Communicating Expert Opinion:
What Do Forensic Scientists Say
and What Do Police, Lawyers, and Judges Hear?

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Statements and Declarations

Declaration of Originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University. The research was approved by the Tasmanian Social Sciences Human Research Ethics Committee (Ethics Reference Number: H0012681).

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Statement of Co-Authorship

The following people and institutions contributed to the publication of work undertaken as part of this thesis:

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Paper 1

Howes, L. M. (2014). The communication of forensic science in the criminal justice system: A review of theory and proposed directions for research. *Science and Justice, 55*(2), 145-154. doi: 10.1016/j.scijus.2014.11.002

This paper is presented as Chapter 2. Loene M. Howes was the sole author on this paper.

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Papers 3-5

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Howes, L. M., Kirkbride, K. P., Kelty, S. F., Julian, R., & Kemp, N. (2014). The readability of expert reports for non-scientist report-users: Reports of forensic comparison of glass. *Forensic Science International*, *236*, 54-66. doi:10.1016/j.forsciint.2013.12.031

Howes, L. M., Julian, R., Kelty, S. F., Kemp, N., & Kirkbride, K. P. (2014). The readability of expert reports for non-scientist report-users: Reports of DNA analysis. *Forensic Science International, 237*, 7-18. doi: 10.1016/j.forsciint.2014.01.007

Papers 3, 4, and 5 are presented as Chapters 4, 5, and 6 respectively. Loene M. Howes was the primary author and primary contributor to the research questions, data analysis, and interpretation for these papers. K. Paul Kirkbride assisted with locating materials for analysis. K. Paul Kirkbride, Roberta Julian, Nenagh Kemp and Sally F. Kelty contributed to the refinement of the paper in their supervisory capacity.

Paper 6

Howes, L. M., Martire, K. A., & Kelty, S. F. (2014). Response to Recommendation 2 of the 2009 NAS Report – Standards for Formatting and Reporting Expert Evaluative Opinions: Where Do We Stand? *Forensic Science Policy and Management: An International Journal, 5*(1-2), 1-14. doi: 10.1080/19409044.2014.880973

This paper is presented as Chapter 7. Loene M. Howes contributed the first section of the paper and developed the structural outline (approximately 60%). Kristy A. Martire and Sally F. Kelty contributed the second and third sections of the paper respectively. All authors contributed to the refinement of the paper as a whole.

Paper 7

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This paper is presented as Chapter 8. Loene M. Howes was the sole author on this paper.

Paper 8

Howes, L. M. (2015). “Sometimes I give up on the report and ring the scientist”: Bridging the gap between what forensic scientists write and what police investigators read. *Policing and Society.* Advance online publication. doi: 10.1080/10439463.2015.1089870

This paper is presented as Chapter 9. Loene M. Howes was the sole author on this paper.

Paper 9

Howes, L. M. (2015). Towards coherent co-presentation of expert evidence in criminal trials: Experiences of communication between forensic scientists and legal practitioners. *Criminal Law Journal, 39*(5), 252-271.

This paper is presented as Chapter 10. Loene M. Howes was the sole author on this paper.

We, the undersigned, agree with the above “proportions of work undertaken” for each of the above published and peer-reviewed manuscripts that contribute to this thesis.

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Abstract

Forensic scientists' expert opinions are used increasingly in the course of police investigations, out-of-court settlements, and trials. For an expert opinion to benefit the community, it must be understood adequately by those charged with using it as a decision-aid. This project aimed to explore the effectiveness of communication about forensic science to police, lawyers, and judges in Australian jurisdictions. Three studies explored the readability of international expert conclusions and Australian expert reports. Content analyses of expert reports of forensic comparison of glass and DNA demonstrated that reports were typically written at a level suited to other experts. The results of these studies were then considered in light of the development of national and international standards for reporting. Based on the studies and analysis of reporting standards, practical recommendations were made to enhance the readability of expert reports, without compromising scientific integrity. Two subsequent studies explored practitioners' experiences of the communication of expert opinion. Police investigators, legal practitioners and forensic scientists participated in semi-structured interviews. Thematic analyses highlighted the value of cross-disciplinary interaction and discussion, not only to foster understanding of expert opinion, but also to assist experts in developing their explanations. Recommendations were made to build on strengths in the communication between forensic scientists and police and legal practitioners within their professional contexts. It is hoped that the recommendations from this project can contribute to increased effectiveness in the communication of forensic science, and therefore to the trustworthiness and integrity of the criminal justice system. Further research, using a case-study approach, could examine the initiatives undertaken to enhance the communication of forensic science in the nuanced contexts of particular jurisdictions.

Acknowledgements

I would like to thank my project supervisors: Associate Professor Roberta Julian, Dr Nenagh Kemp, Dr Sally Kelty (University of Tasmania), and Professor K. Paul Kirkbride (Flinders University). Their gentle and consistent guidance throughout the project has been invaluable. I appreciate Roberta's warmth and her insights into the nature and scope of research on policing, forensic science, and the criminal justice system; Nenagh's considered feedback and expeditious responses; Sally's collegial approach and practical advice; and Paul's insights into the forensic scientific community, and timely clarification of complex concepts. Above all, I have valued the honesty, unwavering encouragement, and enthusiasm for the project that I have received from all supervisors. I hope that our associations may continue for many years.

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1

Introduction – Communicating Expert Opinion: What Do Forensic Scientists Say and What Do Police, Lawyers, and Judges Hear?

Introduction to the Thesis – Communicating Expert Opinion: What Do Forensic Scientists Say and What Do Police, Lawyers, and Judges Hear?

Forensic science, or the application of science to problems of law, is a rapidly developing area of enquiry (Peterson, 2015). The term *forensic science* encompasses a range of techniques from traditional pattern matching techniques, such as handwriting analysis and fingerprinting, to the sophisticated chemistry and biology involved in materials analysis and DNA profiling (Fraser, 2010). *Forensic science* also extends to developing and newer technology-related techniques, such as the recovery of information from mobile phones and computer hard drives (Fraser, 2010). Forensic science is seen to have a role in contributing to justice, serving the wider community, victims of crime, and wrongfully accused individuals. Over recent years, forensic science has been used increasingly in the criminal justice system in the contexts of criminal investigations, out-of-court settlements, and trials (Smith, Bull, & Holliday, 2011).

The first police laboratory was reportedly established in Lyon, France, in 1910 by Edmond Locard, who has often been quoted as one of the fathers of forensic science. The essence of what he said (in French) has been encapsulated in English as “every contact leaves a trace” (Fraser, 2010, p. 2). The notion of solving crime through the traces left at crime scenes is not at all unfamiliar to the general public. Indeed, the development of scientific techniques to assist in solving crime and administering justice seems to be an expected feature of twenty-first century life (Shelton, Kim, & Barak, 2006). Television dramas depicting the role of forensic science in solving crime, such as *CSI: Crime Scene Investigation* and its various offshoots, such as *CSI: Miami*, *CSI: New York* and *CSI: Cyber,* continue to feature in prime time entertainment. Research has demonstrated that a proportion of jurors would require forensic scientific evidence before they would be willing to convict accused persons of certain types of crimes (Goodman-Delahunty &

Hewson, 2010). Forensic scientific evidence is so anticipated by jurors that prosecutors sometimes call forensic scientists to testify about the reasons for a lack of such evidence (Dioso-Villa, 2015; Shelton et al., 2010).

The practice of using forensic science in courts began hundreds of years ago. In an English case in 1554, Justice Saunders was famously quoted as saying:

> If matters arise in our law which concern other sciences or faculties we commonly apply for the aid of that science or faculty, which it concerns. Which is an honourable and commendable thing in our law. For thereby it appears that we do not despise all other sciences but our own, but we approve of them and encourage them, as things worthy of commendation. (Kershaw, 2009, p. 547)

Currently, in Australia under uniform Evidence Law, experts are permitted to give opinions that are based wholly, or substantially, on knowledge from their training, study or experience (Odgers, 2012).

However, the traces left at crime scenes are not necessarily definitive in determining verdicts in criminal trials. The value of forensic scientific evidence depends upon both the nature of the particular science and the circumstances of the case. The 2009 National Academy of Sciences Report, *Strengthening Forensic Science in the United States: A Path Forward* highlighted a number of issues in the forensic sciences. Although conducted in the US, the report has implications for forensic science service provision internationally (see e.g., Cole, 2010; Murphy, 2010; Risinger, 2010). Notably, issues identified in the report included inadequate validation of techniques, limited independence of laboratories from police or prosecutors, and a lack of standard reporting and terminology (NAS, 2009).

While the NAS Report praised DNA profiling, which was deemed a ‘gold standard’ (Liebermann, Carrell, Miethe, & Krauss, 2008), other forensic sciences were deemed to be less scientific by comparison (e.g., NAS, 2009). Facial recognition, for example, has received scathing critiques (Edmond, 2011). Microscopic hair comparison and bite mark identification were shown to have been used with questionable validity (Garrett &

Neufeld, 2009). As recently as April, 2015, a report by the Federal Bureau of Investigation in the United States drew media attention when it acknowledged failings in the administration of justice due to flawed forensic science (Brennan, 2015). Specifically, flawed microscopic hair comparison has been used thousands of times to convict people of crimes over many years (Brennan, 2015). Wrongful convictions on the basis of such evidence reportedly included cases in which the accused people had died in prison and cases in which people had spent many years in prison for crimes they did not commit (Pilkington, 2015).

Innocence Projects in the United States (see www.innocenceproject.org/) have used modern DNA profiling techniques to re-analyse DNA evidence to reveal and overturn 330 past wrongful convictions to date (as at July, 2015). A proportion of such wrongful convictions contained flawed forensic science (including flawed DNA evidence). However, the flaws were not restricted to the science used, but included the way the science was reported, in flawed expert testimony (Garrett & Neufeld, 2009). Flawed communication about forensic science was sometimes introduced in trials by forensic scientists, and sometimes in summing up by lawyers and judges (Garrett & Neufeld, 2009). These regrettable and widely publicised instances of flawed science and reporting of expert opinion have contributed to pressure on a number of disciplines within the forensic sciences to strengthen the scientific basis for their opinions and the effectiveness of communication of them, in line with recommendations of the NAS Report (NAS, 2009).

Focus of the Thesis

This thesis focuses on the communication of forensic scientific findings and expert opinion. The reporting of expert evidence is important, as identified in the NAS Report (2009), because scientific expertise is used in the multidisciplinary arena of criminal justice system as a decision aid by police detectives, lawyers, judges and jurors. For forensic science to be used most appropriately within the criminal justice system, it is essential that forensic scientists communicate effectively to those who use expert opinion to inform their decision-making. It is equally essential that such decision-makers have adequate understanding of the expert opinion presented to them. As noted in the section above, ineffective communication, miscommunication, or misunderstanding of forensic scientists' expert opinions has the potential to contribute to miscarriages of justice (Garrett & Neufeld, 2009).

Despite the use of forensic scientists' expert opinions in a number of contexts within the criminal justice system, such as in investigations and out-of-court settlements, research has focussed overwhelmingly on how well jurors understand expert evidence (see e.g., Dartnall & Goodman-Delahunty, 2006; McAuliff & Duckworth, 2010; McQuiston-Surrett & Saks, 2008, 2009). Police investigators, lawyers, and judges are also non-scientists who may struggle to comprehend the nuances of forensic scientists' findings (de Keijser & Elffers, 2012; Strom & Hickman, 2010). Although the effectiveness of communication about forensic science to police, lawyers and judges has potential implications for the ways in which cases are processed through the criminal justice system, the nature of such communication is an under-researched issue.

Aims and Scope of the Project

This PhD project is an interdisciplinary project, which is located in both the Tasmanian Institute of Law Enforcement Studies (TILES), within the School of Social Sciences, and in the Division of Psychology in the School of Medicine, at the University of Tasmania. The project was supported by an industry partnership with the Australian Federal Police. The aim of the project was to assess and improve upon current practices of the communication of scientific expert opinion between the forensic scientists who produce this opinion and the groups (police detectives, lawyers, judges, and jurors) who use this opinion in their roles within the criminal justice system.

Given the highly specialised nature of DNA analysis, its increased use in the criminal justice system, and the complexity of reporting it in probabilistic terms, forensic biology (DNA) was selected as a discipline for consideration. As a second discipline, forensic chemistry (forensic comparison of glass) was selected because it also requires highly specialised study, and statistical calculations are used in some Australian laboratories to support interpretations. Additionally, this is the field of expertise of Dr K. Paul Kirkbride, who at the start of the project was the Chief Scientist at the Australian Federal Police, and the Scientific Advisor for the project. (Paul is now Professor of Forensic Science at Flinders University.)

The research project focuses both on the formal reporting of forensic scientists' expert opinion through written reports and expert testimony and on more informal communication in investigative and pre-trial contexts. The research project takes place in the context of the Australian legal system among participating jurisdictions. Given that the international forensic scientific community is relatively small, the study may have international implications. However, the results of some studies comprising the project may be more easily generalised to different jurisdictions and countries than are others.

Significance of the Project

This project has potential practical implications in terms of the way that forensic scientific findings and opinions are reported, understood, and therefore used in criminal justice settings. Greater comprehension of results in less time, if achievable, for example, would allow more efficient use of police time in decision-making about abandoning or pursuing particular lines of investigation. If forensic scientists' reports are more readily understood, judicial gatekeepers may more readily be able to determine their reliability and decide matters of admissibility with greater ease. Better comprehended reports may be more likely to be used effectively by lawyers in both prosecution and defence, with lawyers asking more relevant and better-informed questions of expert witnesses in examination and cross-examination. If the recommendations can lead to greater juror comprehension, the safety of verdicts may be enhanced. This would contribute to the effectiveness of the criminal justice system with benefits including better use of financial resources and time, and increased trustworthiness of the system.

More specifically, the main proposed contribution of the research was to identify the theoretical principles of effective communication about expert opinion, in written and verbal forms, to best meet the needs of the providers and users of such opinion. On a practical level, the outcomes include recommendations based on these theoretical principles, to enhance the reader-friendliness of expert reports for non-scientists, while ensuring that scientific accuracy is not compromised. Recommendations for case-reporting forensic scientists include suggested ways to enhance user-friendliness and reader-comprehension of expert reports. Further recommendations include suggested focus areas for professional development for police detectives, legal practitioners, and forensic scientists.

Presentation of the Thesis

In writing this thesis, given that reporting expert opinion is a topical issue, it was my intention to make the results of the studies available to the forensic scientific community as soon as possible. With the exception of this introduction and the conclusion (Chapters 1 & 11), I present the thesis as a series of discrete papers, some of which have already been published in peer-reviewed journals (Chapter 2, & Chapters 4 - 8), accepted for publication in peer-reviewed journals (Chapter 10), or submitted for publication to such journals (Chapters 3 & 9). In general, the papers were published in the sequence in which they are presented in the thesis, with the exception of Chapter 2, which was published after the document studies (Chapters 4-6) had been completed. I have endeavoured to avoid undue overlap in the content of different papers and ask readers for their forbearance in instances where overlap in background information was necessary. The papers have been published in journals with different stylistic requirements. For their presentation in thesis format, I have adopted the referencing style of the American Psychological Association (6th ed. [APA], 2010). References are included at the end of each chapter, rather than in a common list at the end of the thesis. The thesis consists of ten further chapters in five parts.

In **Part 1**, following this introduction, Chapters 2 and 3 provide the theoretical background and rationale for the research project. Specifically, in Chapter 2, I discuss the theoretical underpinnings of communication about forensic science to guide the enquiry. Drawing on models of science communication, I develop a model of communication about forensic science. I use the model as an organisational framework for a review of past research and legal commentary on the communication about forensic science. From this basis, the rationale for the current research project is developed. I argue for the need to investigate the effectiveness of communication of forensic scientists' expert opinions to those who use the opinions within the criminal justice system. The most pressing aspects of communication about forensic science in need of future research are identified.

In Chapter 3, I present a justification for the approach to research methodology selected for the project overall. The approach used was a mixed-methods approach, within a paradigm of dialectical pluralism, which values the perspectives of stakeholders drawn from different disciplines. In this chapter, I reflexively consider my role as a researcher and discuss the philosophical underpinnings of the chosen approach to research methodology. The foundations presented in this chapter can be seen to guide methodological decision-making throughout the project. The chapter focuses on the broad overview of the project as a whole, leaving more specific methodological detail for the specific studies that comprise the overall project (Chapters 2-4, 7, & 8).

The chapters of **Part 2** consist of document studies, in which I examined the readability of expert reports. Chapter 4 reports a two-part study of the readability of expert conclusions. The sample of conclusions was drawn from the public domain and consisted of forensic scientists' responses to a proficiency test on the forensic comparison of glass. Following the initial study of documents drawn from the public domain, Chapter 5 reports a study of the readability of experts' reports arising from casework forensic comparison of glass. The reports were drawn from six Australian jurisdictions (states and territories). The research method used to examine the readability of conclusions was further developed and refined for use with entire reports. Chapter 6 reports a study in which the research method developed in Chapter 5 was applied to an analysis of the readability of expert reports of DNA analysis. An additional paper, written for researchers and research students interested in exploring content analysis, is presented in the Appendix.

In the two chapters of **Part 3**, I discuss the implications of the document studies presented in the preceding part. In Chapter 7, along with two co-authors (Kristy Martire and Sally Kelty), I consider the findings from the three document studies in light of the Australian Standard on forensic reporting (Standards Australia, 2013) and Recommendation 2 from the *Report on Strengthening Forensic Science in the United States* (NAS, 2009). In Chapter 8, based on the findings from the document studies, I present recommendations for case-reporting scientists to enhance the readability of their expert reports for non-scientists.

In **Part 4**, I explore practitioners' experiences and perceptions of the effectiveness of communication about forensic science. Specifically, in Chapter 9, I report the findings from a study in which I interviewed police investigators, police liaison officers (including crime scene examiners and triage officers) and forensic scientists (biologists and trace evidence examiners) about their perceptions the effectiveness of communication of expert opinion. The model of communication of forensic science discussed in Chapter 2 was used in analysis of the interview transcripts. Themes from interviews are discussed in light of the communication model. The chapter makes recommendations to enhance the communication about forensic science through: (a) problem-based approaches to education in forensic science for police recruits and detectives in training programs; and (b) increased opportunities for interaction between police investigators, liaison officers and forensic scientists.

In Chapter 10, I report the findings from the interviews with forensic scientists about their communication with legal practitioners and in the courts. Included in the study are the findings from interviews with legal practitioners (judges of the Supreme Court, Crown prosecutors, and criminal defence lawyers). The chapter discusses the uneven structure of pre-trial communication between forensic scientists and legal practitioners depending on their professional roles. The chapter identifies concerns shared by forensic scientists and legal practitioners and proposes that such shared concerns can act as a bridge to foster greater cross-disciplinary understanding between scientists and legal practitioners.

Finally, in **Part 5**, Chapter 11 summarises the contributions of the thesis overall. It considers some of the limitations of the project and identifies areas in need of further research in the communication of expert opinion. It concludes that ongoing research in this domain is warranted in light of further developments in forensic science, changes in legal contexts, and local nuances in different jurisdictions.

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Part 1

Background and Approach

2

The Communication of Forensic Science in the Criminal Justice System: A Review of Theory and Proposed Directions for Research

This chapter has been published as follows:

Howes, L. M. (2014). The communication of forensic science in the criminal justice system: A review of theory and proposed directions for research. *Science and Justice, 55*(2), 145-154. doi: 10.1016/j.scijus.2014.11.002

Abstract

Clear communication about forensic science is essential to the effectiveness and perceived trustworthiness of the criminal justice system. Communication can be seen as a meaning-making process that involves different components such as the sender of a message, the message itself, the channel in which a message is sent, and the receiver of the message. Research conducted to date on the communication between forensic scientists and non-scientists in the criminal justice system has focused on different components of the communication process as objects of study. The purpose of this paper is to bring together communication theory and past research on the communication of forensic science to contribute to a deeper understanding of it, and to provide a coherent view of it overall. The paper first outlines the broader context of communication theory and science communication as a backdrop to forensic science communication. Then it presents a conceptual framework as a way to organise past research, and using the framework, reviews recent examples of empirical research and commentary on the communication of forensic science. Finally the paper identifies aspects of the communication of forensic science that may be addressed by future research to enhance the effectiveness of communication between scientists and non-scientists in this multidisciplinary arena.

The Communication of Forensic Science in the Criminal Justice System:

A Review of Theory and Proposed Directions for Research

Communication is an essential component of science. In fact, it has been suggested that in accordance with the scientific model, "communicating *is* the doing of science" (Montgomery, 2003, p. 1). For forensic scientists, the primary audience for their communication of findings is not other scientists, but a range of non-scientists including police investigators, lawyers, judges, and jurors (Cole, 2013). The necessity for clear and accurate communication of forensic science arises because forensic scientists' findings are used as decision-aids in police investigations, out-of-court settlements, and trials. However, scientific language is a specialist language with grammatical features that make it differ substantially from language in use in the general community (Halliday, 1993). Furthermore, considerably different specialist languages are used in science and law (Taroni, Biederman, Vuille, & Morling, 2013), and this contributes to the difficulty of achieving clear communication.

A powerful illustration of the potential issues of ineffective communication in the forensic science arena was provided by Garrett and Neufeld (2009), who examined past miscarriages of justice. These researchers examined 232 cases of post-conviction DNA exoneration in the United States. Of the original trials, 156 trial transcripts contained scientific expert evidence; 137 such transcripts were located and examined. Invalid expert testimony, defined as "a conclusion not supported by empirical data" (Garrett & Neufeld, 2009, p. 7), was found in 82 (60%) of the 137 cases. The issues with communication of scientific findings were not limited to particular laboratories, scientists, or scientific disciplines (although serology and microscopic hair analysis were both commonly used in the cases and accounted for substantial proportions of the invalid testimony). The study implicated 72 scientists and 52 laboratories or hospitals in 25 US states. In addition, errors were introduced by prosecution lawyers in closing, and tended not to be challenged by defence lawyers who seldom had access to their own expert scientists. Nor was the science of individual cases questioned by judges as they admitted particular scientific methodologies as reliable (Garrett & Neufeld, 2009). It was by no means suggested that the miscommunication of forensic science was solely responsible for the miscarriages of justice in these cases. However, this study highlighted the real potential for misinterpretation, miscommunication, or misunderstanding of science to contribute to miscarriages of justice.

The issue of communication was raised in the 2009 National Academy of Sciences (NAS) Report on *Strengthening Forensic Science in the United States: A Path Forward*. This influential report found that communication of forensic science lacked adequate consistency of form and language and recommended the development of model report templates for each forensic discipline, as well as the development and use of standard terminology (National Academy of Sciences [NAS], 2009). Since the release of the NAS Report, the European Network of Forensic Science Institutes (ENFSI) has worked on a 3-year project called *Strengthening the Evaluation of Forensic Results across Europe* (ENFSI, 2013a) to develop and implement standards for reporting forensic evidence (ENFSI, 2013b). Similarly, Standards Australia has developed four standards for forensic science, including one on Reporting (Robertson, Kent, & Wilson-Wilde, 2013). Whilst the issue of communication of forensic science has long been a topic of research interest, since the release of the 2009 NAS Report it has received increased attention as a priority from forensic scientists, legal scholars, and behavioural and social scientists.

The purpose of this paper is to contribute to a deeper understanding of the issues of forensic science communication and to develop a rationale for future research aimed to further improve the communication of expert evidence to non-scientists. To achieve this aim, the paper presents four sections. First the current approach to the communication of forensic science is identified and located within the broader domain of communication theory and science communication. Next, based on the broader context of communication theory, a model of communication is proposed that can be used as a conceptual framework around which to organise past research on communication of forensic science. Third, examples of existing empirical studies and legal commentary are briefly reviewed to demonstrate the utility of the conceptual framework. Finally, some potentially fruitful areas for future research on communication of forensic science are suggested in light of the review presented.

1. Approaches to Communication

The study of communication has its origins in diverse disciplines, such as mathematics, psychology, sociology, and linguistics (Craig, 1999). According to Craig, each discipline has its own perspective on communication, with a multitude of definitions and theories that are useful in their contexts, but are largely unrelated as a field.[1] Communication theories have been classified by disciplinary origin, level of organisation, underlying epistemology, and "underlying conceptions of communication practice" (Craig, 1999, p. 135; namely: rhetorical, semiotic, phenomenological, cybernetic, socio-psychological, socio-cultural, and critical conceptions). Craig suggested that scholars from the discipline of communication (as distinct from other academic disciplines also studying communication) may be united by a common view of communication as the primary constitutive social process. According to this view, it is the aim of understanding and being understood that leads to communicative behaviours, including language. Many of the theoretical perspectives on communication and the various theories that constitute these

[1] For examples from the range of communication theories, some of which may be applied to an analysis of forensic science communication see, for example, the Overview of Communication Theories provided on the University of Twente website: http://www.utwente.nl/cw/theorieenoverzicht/

approaches may offer explanatory utility to the analysis of particular aspects of the communication of forensic science. However, in terms of characterising the communication of forensic science overall, it is worthwhile to consider communication broadly as a one-way linear process versus an ongoing and contextual one.

The idea of the existence of key components of communication was famously expressed by Lasswell (1948, p. 37) as: “who says what, in which channel, to whom, and with what effect?” Similarly, Jakobson (1960) described the speech acts as an “addresser” giving “a message” to an “addressee” in a “context” in a mutually shared (or at least partially shared) “code” and via a “contact” (channel). Shannon and Weaver (1949) proposed a model, which captured the key components of communication in a simple heuristic that found widespread appeal in many communication contexts (Craig, 1999; see Figure 1).

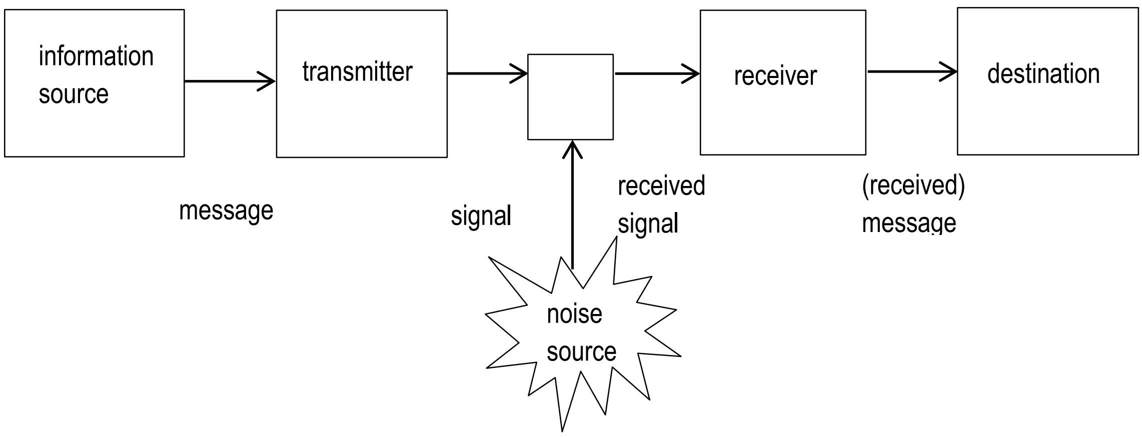

Figure 1. Shannon and Weaver’s model of communication (Shannon & Weaver, 1949). From *The Mathematical Theory of Communication*. Copyright 1949, 1998 by the Board of Trustees of the University of Illinos. Used with permission of the University of Illinois Press.

The model was able to account for the notion that the sender had to encode the message (into sounds or symbols) to be decoded by the receiver, who shared a knowledge (at least in part) of the sounds or symbols used. In addition, the model incorporated noise, described as an interference with signal transmission (e.g., social, cultural, and psychological influences) that meant that the signal received differed from the one sent (Shannon, 1948).

Although it has endured over time, the transmission model has been criticised as a representation of interpersonal communication for a number of reasons. Perhaps the most significant criticism is that it fails to depict the dynamic nature of communication, representing it as linear and static (Craig, 1999). The 1948 transmission model was later updated to include feedback in the system, which in terms of interpersonal communication may include written, verbal, para-verbal (e.g., tone of voice) and non-verbal (e.g., facial expressions and body language) communication from the receiver to sender (see Figure 2). Another key criticism of the transmission model was that it did not prioritise the *meaning* of the message sent. Although Shannon did acknowledge that the meaning of communication could be an aspect to consider, the intended purpose of the model had been to consider engineering issues in telecommunications (Shannon, 1948).

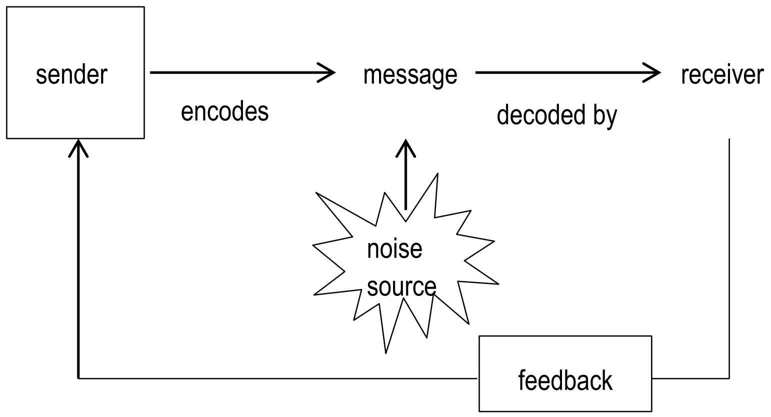

Figure 2. Transmission model of communication with feedback from receiver to sender.

More recent approaches to communication that recognised the importance of meaning proposed more dynamic representations of two-way interaction (with dual sender/receiver roles); or continuous, ongoing, and open-ended interaction, as meaning was negotiated. Many such approaches are similar in that they represent constructivist perspectives (Campos, 2007), which hold that knowledge and communication are contextually situated. Such approaches emphasise meaning making as an interactive negotiation between the parties to the communication within the particular context.

However, despite widespread acceptance of constructivist approaches to interpersonal communication, such approaches are not always appropriate for describing communication processes because this is dependent upon the amount of interaction possible in the particular channel discussed (Dixon & Bortolussi, 2001). For example, whilst it could be argued that scientific communication through conferences, peer-reviewed journal articles, and face-to-face lectures provides a form of two-way communication (to varying degrees), speeches on the radio provide one-way communication, due to the lack of feedback possible from the audience (Dixon & Bortolussi, 2001). Similarly, text is not communication in the same way as is dialogue due to the lack of opportunity for the reader to interact with the writer or speaker to correct errors in understanding and to negotiate and co-create shared meaning (Dixon & Bortolussi, 2001). For forms of communication in which interaction – or at least a feedback loop – is not available, the meanings of texts are necessarily constructed by the reader interacting with the text, as opposed to being co-constructed or negotiated with the writer. For these types of reasons, Craig (1999) acknowledged that the transmission model may have broad value in considering communication and it continues to hold popular appeal.

Communication of Science

Against the backdrop of diverse approaches to communication, there exists the field of science communication, which concerns both the dissemination of scientific research, and models of public engagement (Bubela et al., 2009). Science communication has been described as occurring along a continuum of audiences from specialist scientist peers, to scientists from related fields, to people interested in science, and finally to the general public(Bucchi, 2008). Such a continuum, anchored at one end by specialist peers and at the other by a generalist public (Bucchi, 2008), provides a useful heuristic to represent the level of specificity or generality of the communication about science. This continuum acknowledges that the audiences for science communication vary in the extent to which they share an understanding of specialist scientific language with the scientist. Although several potential audiences for science communication exist, in practice, the teaching of science communication is a twofold enterprise, involving communication at the ends of the continuum: to scientist peers, and to the general public. It cannot be assumed that all scientists, including forensic scientists, have been explicitly educated in the art of communicating science to generalist as well as specialist audiences.

Scientists' communication with scientific peers. Generally, the audience of scientific communication is assumed to be scientist peers (Schickore, 2008). Science is communicated to scientist peers through speeches and poster presentations at conferences, refereed journal articles, invited comments on journal articles, and research proposals building upon previous results (Schickore, 2008). Through communication with peers, results can be re-tested by others and arguments can be refined; thus, the pool of scientific knowledge can be increased incrementally.

In becoming educated in science, scientists gain specific skills and internalise the communication norms of the scientific community, adopting scientific discourse as a way of being (Magnifico, 2010). Magnifico (2010) distinguished this all-encompassing notion of discourse from one that merely considers the type of language used. Scientific discourse can be seen to encompass situated practices and specific ways of thinking, talking, writing, acting, and believing. The audience of other scientists, for whom scientists may typically write, can also be seen as part of this discourse, rather than external to it. Thus, mastering scientific communication means mastering the way the scientific community understands the world (Magnifico, 2010).

The norms and practices of scientific writing were examined by Roland (2009) in a study of several hundred scientific manuscripts. The manuscripts included those accepted and rejected for publication by journals from a broad range of scientific disciplines, as well as reviewers' reports, scientific writing manuals, and author guidelines of scientific journals. Scientist authors avoided the use of the first person (*I* or *we*), making it difficult for the reader to distinguish between the hypotheses reported from previous literature and the author's own hypotheses. They avoided making declarative statements, preferring to hedge (with use of words such as "may"). Scientists made long noun strings and turned them into acronyms, creating complex and unfamiliar terms. According to Roland, they rarely used topic sentences to start paragraphs, and often used linking words (e.g., “however, besides, nevertheless, moreover”; Roland, 2009, p. 4), to move the reader back and forward in the author’s thought process.

A number of the features identified by Roland (2009) can be considered standard features of scientific language that are reinforced in tertiary science education and professional practice. These include the use of the passive voice, the use of specialised terms that are interrelated with other specialised terms, the abstract nature of sentences that are densely packed with content, and the authoritativeness of scientific language (Halliday, 1993). Such features contribute to the difficulty for non-scientists in understanding the science. In fact, Halliday (1993) contended that understanding science was synonymous with understanding the language of science.

It should be noted that even though the communication of science to scientist peers is essential to the ongoing development of science, often, the explicit teaching of academic communication skills is limited. Science students’ writing tasks once typically consisted of the writing of laboratory reports (Moskovitz & Kellogg, 2011). Increasingly, best practice in science communication suggests that students be given a foundation to understand and critically analyse the scientific literature (Feldman, Anderson, & Mangurian, 2001). Science students are taught to write in the style of journal articles, oftentimes even incorporating a revision process (Morgan, Fraga, & Macauley, 2011). Ideally, science students become accustomed to providing and receiving peer review, and giving conference-style presentations (Whelan & Zare, 2003). In short, the communication of science, as taught in science degrees, focuses on academic communication to prepare science students, including those who move into forensic science, for academic careers as scientists.

Scientists’ communication with non-scientists. Recognition of the difficulties of communicating science to popular audiences has led to new roles in the communication of science. Intermediaries known as *science communicators* may include university professors, researchers, consultants, and science journalists (Roland, 2009). Although teaching science students to communicate science to a general or popular audience has not been a goal of science degrees, in response to demand, a number of universities have introduced science communication degrees designed to improve science communication to the popular audience (Longnecker, 2009). Such courses are taught in both science communication degrees and within science degrees as elective subjects (Longnecker, 2009).

Educators who teach science communication courses urge writers to develop flexibility in their writing, to experiment with writing, and even to make use of features of other styles and genres of writing to develop writing skills (Bushnell, 2003). In such contexts, the scientist behind the science may be central to a story and the use of the first person and a subjective viewpoint can be employed to add interest (Bushnell, 2003). It is emphasised that safe, formulaic writing without consideration of context, audience and purpose is counterproductive to good writing (Wiggins, 2009).

Within the sociology of science, it has been convincingly argued that neither science nor the communication of it is value free because science is embedded within culture (Bushnell, 2003). Communicators of science, including forensic science, whether scientists or others, necessarily make decisions about what is to be explained, what is to be emphasised, and what can be given less attention or even omitted. For example, when journalists explain science, they do not use scientific criteria for truth and accuracy but apply criteria from journalism (Peters, 2008). Although scientific findings can be widely disseminated when popular media are used (Bubela et al., 2009), the amount of time allocated to a topic may be limited, and misleading frames for it may be selected on the basis of political agendas or research that shows the topics of interest to the audience

(Peters, 2008). In addition to the issue of framing, the notion that scientific ideas expressed in scientific language can simply be “translated” into the lay language in general use has been criticised on the basis that scientific language and day-to-day language are not equivalent (Peters, 2008).

The non-equivalence of scientific and lay language is reflected in the differing levels of specificity employed along the continuum of the communication of science. As one moves along the continuum, the language of science shifts (Bucchi, 2008). This shifting language in the communication of science is exemplified by the communication of uncertainty. As noted by Roland (2009), when scientists communicate with other disciplinary or interdisciplinary specialists (e.g., via scientific journals), language is tentative and “hedge words” (e.g., “may”) are characteristically used to communicate a degree of uncertainty (Bucchi, 2008). In contrast, communication with a general audience tends to employ terms that convey certainty. Once science reaches the level of generality of a text book, it is typically communicated as fact assumed to be widely accepted by the scientific community, and once it reaches the popular audience, there may be a lack of nuance (Bucchi, 2008). Thus, there exists the risk that as the language of science becomes more accessible and comprehensible, it becomes less precise and less accurate. From the perspective of the forensic scientist, although audience understanding is desirable, decreased accuracy and precision are highly undesirable as the accurate communication of the uncertainty of conclusions and the strength or the weight of evidence are of utmost importance.

Models of the communication of science to non-scientists. Three key models that describe the communication between scientific experts and the public are of relevance. Arranged from least to most interaction between scientists and non-scientists, these are: the deficit model, the dialogue model, and the participation model (Bucchi, 2008; Trench, 2008). However, rather than a static approach to communication of science to the public, with a single model representing all instances, the model of communication in use varies depending upon context (Bucchi, 2008).

The deficit model. The deficit or dissemination model emphasises knowledge asymmetry and represents a one-way *transfer of knowledge* from scientists to the public. The dominant paradigm used to describe science communication has been one of knowledge transfer (Bucchi, 2008); this is consistent with a transmission model of communication. Essentially, the deficit model assumed that the scientist was a repository of knowledge and would transmit that same knowledge to the audience who lacked the knowledge. This model has typically been adopted in science communication to the public (Bucchi, 2008), including in court cases.

Forensic science evolved in a historical context where the court recognised that specialised knowledge could contribute to decisions about the facts of a case (Mnookin, 2001). Expert opinion developed to assist the courts on matters about which laypersons could not be expected to know. A deficit model is used in the criminal justice system in two key ways: (1) deference to scientists' authority; and (2) education by scientists. It has sometimes been assumed that while police investigators can defer to scientific knowledge, scientists must educate jurors and judges about the science because judges and jurors, not scientists, must find facts and decide verdicts (Roberts, 2009). However, as Mnookin (2001) illustrated with the example of handwriting analysis, education can be a form of deference, just as it is in the classroom. Mnookin argued that when a handwriting specialist taught judges or jurors how genuine specimens of handwriting could be distinguished from forged specimens "the experts simultaneously taught fact-finders that handwriting experts were worthy of credence and deserving of deference" (Mnookin, 2001, p. 1826).

The dialogue model. The focus of the dialogue model is social responsibility and discussing the implications of research in a *two-way negotiation* or consultation between scientist and the public and public to scientist (Clarke, 2001). During the past decade growing public demand for involvement in issues and contribution to the debates has led to a rethinking of the meaning of public communication of science (Bucchi, 2008). The dialogue model is appropriate for issues where the public would like to have input into decisions, such as in public health and ethical matters (e.g., genetically modified food and stem-cell research). There have been calls for forensic scientists to engage in public discussions about ethical and human rights issues regarding, for example, the collection and storage of DNA samples, and the use of DNA databases (Donnelly, 2012). Within the criminal justice system, in pre-trial meetings between forensic scientists and lawyers to discuss the science relevant to a case, a dialogue approach may be in use.

The participatory model. The participation or engagement model features a civic science, where the public sets the aims, and shapes the agenda of the research in an open-ended context of *knowledge co-production*. The participation approach is appropriate when stakeholders are actively involved in decisions about what to research, such as in agricultural science. A participation approach embraces constructivist ways of knowing (Röling, 1996) and aims to value multiple perspectives and different ways of knowing, without privileging scientific knowledge above lay knowledge.[2] It has been used successfully in environmental decision-making in Canada (Kelsey, 2003). Shared decision-making has been advocated in medicine, with calls for doctors to present their knowledge, complete with uncertainty, to patients in informing their decisions about the selection of potential treatments (Kasper, Légaré, Scheibler, & Geiger, 2011). In the criminal justice

[2] It is important to note that although the criminal justice system explicitly values lay knowledge and participation by including lay people as jurors, the communication of forensic science to those jurors within a trial more closely reflects a deficit approach.

system, when forensic scientists and police investigators together discuss a serious crime and prioritise the items to examine scientifically (Kelty, Julian, & Ross, 2013) a participatory approach may be in use.

2. A Conceptual Model of Forensic Science Communication

As noted above, examples of all three models of science communication are present in the context of the criminal justice system in the communication of forensic science. In the communication of science to the public, the widespread adoption of the deficit model as a representation of communication has been criticised for a range of reasons. For example, the model is linear and represents a one-way process, in which scientific discourse is privileged and seen to influence public discourse, but not the other way around (Peters, 2008). However, in forensic science, due to the existence of studies that have revealed the potential for contextual bias (Kassin, Dror, & Kukucka, 2013), dialogue and participatory approaches may be viewed with caution. Furthermore, the legal context presents a formal and traditional environment. In such an environment, communication is constrained in ways that decrease interaction between the parties to the communication. For example, forensic scientists formally communicate their results to police investigators and lawyers in written reports; time and budget constraints limit the interaction between scientists and lawyers in pre-trial contexts (Cashman & Henning, 2012); and jurors cannot direct questions to the scientist as they arise during a trial, but must formulate their questions in the jury room and later direct them to the judge. The result of such constraints is that communication is asynchronous and cannot flow freely. On balance, it seems that the deficit model provides the best overall representation of forensic science communication.

Given that the communication of forensic science can best be described by a deficit approach to science communication, a modified version of the Shannon and Weaver model seems appropriate. However, to take into account the importance of the communication context and constructivist notions of meaning making, the model has been updated to include the broader social and legal contexts of the communication and the purposes for which the message was created by senders (forensic scientists) and applied by receivers (police, lawyers, judges, and jurors), depending upon their roles in the criminal justice system (see Figure 3). The channel of communication can be seen to incorporate both the level of formality of the communication and the degree of interaction between scientists and non-scientists.

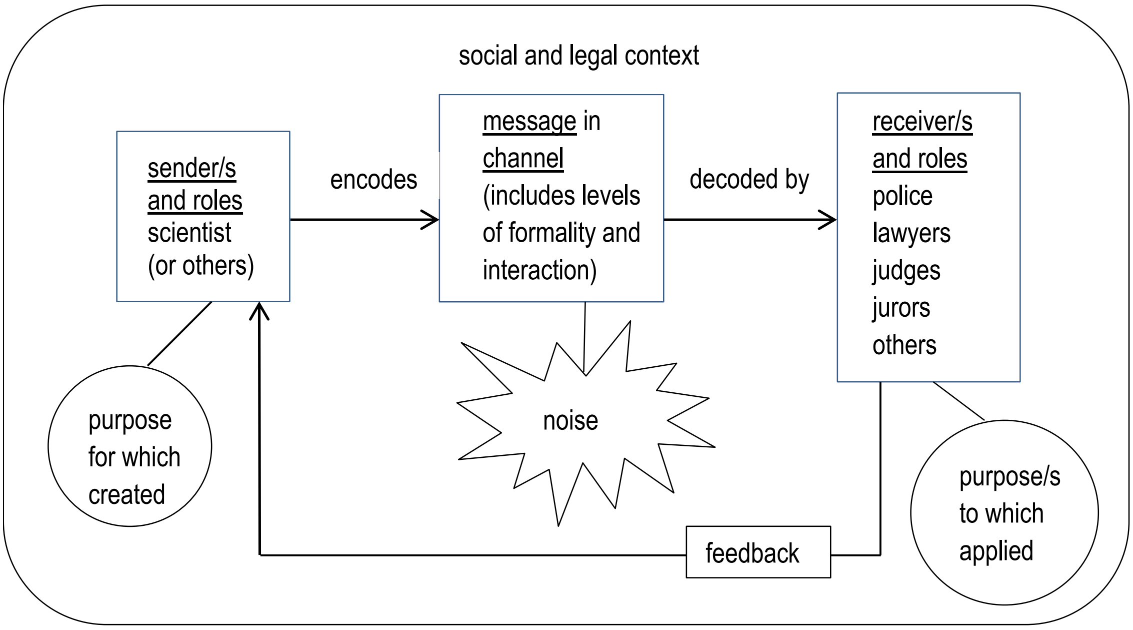

Figure 3. Conceptual model of the communication of forensic science.

3. The Communication of Forensic Science

Using the conceptual model of the communication of forensic science (Figure 3), examples are provided of empirical research or legal commentary for each component of the communication and the added context and purpose. The following review is not intended to provide a comprehensive overview of all relevant research and commentary, but a general indication of the scope of the field. The classifications presented are tentative and not necessarily mutually exclusive. In some instances, researchers may have considered more than one communication component as the object of interest, and it may be possible to locate the same studies under a number of communication components. In most instances, the studies have been classified by the main object of investigation. Where applicable, the studies are organised chronologically in the process from crime scene to court.

The Context of Communication

Research about the communication of forensic science in the criminal justice system has examined elements of the broader social and legal contexts.

The social context. Research in this area has considered the influence of media, and changing social expectations in light of advances in science and technology. For example, Shelton, Kim, and Barak (2006) conducted a study to investigate whether viewing of television dramas such as the popular US crime scene investigation series *CSI* (crime scene investigation) had an effect (the “CSI effect”; Podlas, 2005) on juror expectations of scientific evidence in trials. Over one thousand people called for jury duty were surveyed about their expectations for scientific evidence, requirement of scientific evidence for guilty verdict, and demographic information including television viewing habits. Findings provided little support for the idea that viewing CSI-type television programs led to increased expectations of scientific evidence in trials. Instead, the researchers concluded that jurors’ expectations of scientific evidence in trials were the result of increased knowledge about scientific and technical advances more generally, and could best be described as a broader “tech effect”.

Related to the tech effect, is the “white coat effect”. It has been argued that the authority and status given to science in the wider society can decrease the value that lay people place on their own knowledge and views (Peters, 2008). The deficit approach to communication (with scientist as expert) may reinforce cultural beliefs in which experts are valued as reliable sources of information (Craig, 1999). However, in a simulated homicide trial tested using 12 mock juries, no evidence was found to support the existence of a white coat effect when scientific evidence was presented by both prosecution and defence (Goodman-Delahunty & Wakabayashi, 2012) nor was a white coat effect supported when DNA evidence was presented by a single expert, led either by the prosecution or the judge (Goodman-Delahunty & Hewson, 2010). This suggests that non-scientists are used to engaging with science and technology in general life, and despite its complexity, are not necessarily in awe of scientific knowledge.

The legal context. The context of the adversarial trial constrains and regulates the way that scientists can present expert evidence. Thus, researchers have considered the approaches to the communication of forensic science permissible within existing legal structures. In the courtroom context in the adversarial system, usually, a single expert is called by the prosecution and cross-examined by the defence (Goodman-Delahunty & Wakabayashi, 2012). However, in a simulated trial for homicide, support was found for the use of a defence expert in minimising jury error about the weight of the scientific evidence. In addition, other traditional legal safeguards, including instruction from the judge about how to weigh the forensic evidence and jury deliberation were supported (Goodman-Delahunty & Wakabayashi, 2012).

Researchers have considered various approaches to the communication of forensic science in the adversarial and inquisitorial legal systems. The adversarial system is characterised by unequal access to forensic experts for prosecution and defence (Findley, 2008). Due to the presence of court-appointed experts in the inquisitorial system (Vuille, 2013), it may seem that the inquisitorial system offers a solution to this issue of disparity. However, citing a 2011 study she conducted in Switzerland, Vuille (2013) documented that neither the judges, nor lawyers (prosecution and defence) perceived that it was their role to question scientific (DNA) evidence. Vuille (2013) cautioned that the inquisitorial system, in its current form, was ill-equipped to cope with advances in forensic sciences when questions of a scientific nature arose in relation to a case. The inquisitorial system was limited by the fact that judges were not required to be educated in science and tended to have high levels of trust in the truth of science, while lacking awareness of its limitations (Vuille, 2013).

Similarly, the issue that judges use legal precedent rather than scientific validity to assess the science admitted to court has been highlighted in the adversarial system (Edmond & San Roque, 2012). Traditional legal safeguards have been characterised as inadequate for ensuring that only reliable science is admitted to the courts (Edmond, 2011; Findley, 2008) as judges are unlikely to possess the in-depth knowledge of science required to assess its rigour (Edmond & Roach, 2011). It has been proposed that an institutional panel of scientists (Findley, 2008) or a multidisciplinary advisory panel (Edmond, 2012) could advise judges, to alleviate some of the burden in determining the admissibility of scientific evidence.

The Purpose of Communication

Researchers have considered the mismatch of questions asked by courts, versus the questions asked by forensic science. While forensic science often aims to classify (determine the nature of) a questioned sample and then compare it (to determine whether and to what extent it can be associated) with a reference sample, the courts use the resulting information to help address the ultimate issue (i.e., to decide a legal verdict of “not guilty” or “guilty” beyond a reasonable doubt; Aitken, Roberts, & Jackson, 2010). This idea has been explained as addressing differing levels of propositions (Taroni, Biederman, Vuille, & Morling, 2013). Forensic science often aims to address a question about the source, such as “Whose DNA is this?” by considering a pair of source-level propositions (e.g., the DNA from the crime scene is from the suspect versus from an unknown person) or a pair of activity level propositions (e.g., the person was close to a particular window when it was broken or was involved in an unrelated incident involving broken glass). In fact, Taroni et al. (2013) noted that science often considers propositions at the level of subsource (which does not consider the crime context; e.g., the DNA comes from the suspect versus the DNA comes from an unknown person).

However, the courts aim to address a proposition at the level of offence. An answer to a question about “Is this the suspect’s DNA?” cannot answer the question of “How did the DNA get there?” (activity level proposition), let alone a question such as “Did the suspect commit the crime?” (offence level proposition). Taroni et al. (2013) cautioned against an assumption that support for a source-level proposition implied support for an activity-level or offence-level proposition. Simply put, the presence of DNA at a scene does not mean that the suspect left the DNA there. Even if the suspect did leave the DNA there, it does not mean that the suspect committed the crime. Without adequate consideration of this logic during trials in which scientific evidence is used, the hierarchy of propositions could be violated and flawed decisions made (Taroni et al., 2013). In Australia, the potential for such flawed logic was exemplified in the case of *R v Jama,* in which a man was convicted on the basis of DNA evidence alone for a crime he had not committed. After he had spent 16 months in prison, it was found that the DNA sample had been contaminated and a serious miscarriage of justice had occurred (Vincent, 2010), highlighting the importance for legal decision-makers that forensic science be used to contribute to, rather than replace, sound judgements.

The Sender

This category has included research about attributes of the senders. Researchers have considered the effectiveness of a single expert compared with separate experts for prosecution and defence, a court-appointed expert, or a panel of experts giving concurrent evidence (“hot-tubbing”). In one such study, 470 mock jurors participated in an online simulated criminal trial with DNA evidence presented by an expert introduced by the judge or by the prosecution, while a control group was told that DNA evidence was inconclusive (Goodman-Delahunty & Hewson, 2010). Trust in the expert evidence was higher overall when the expert was introduced by the judge than by the prosecution; however, more knowledgeable jurors were not influenced by the association of the expert with the judge or prosecution (Goodman-Delahunty & Hewson, 2010). Researchers have also considered how experts’ credibility as perceived by judges and jurors can best be measured in the research context (Brodsky, Griffin, & Cramer, 2010) and how scientists’ skills in communicating complex concepts to non-scientists can be enhanced (Kelty & Julian, 2014).

The sender of the message about forensic science is not necessarily the scientist, but may include others such as police investigators, lawyers, judges, and jurors as well (Garrett & Neufeld, 2009). This is important not only in the context of errors being introduced into communication of forensic science; non-scientist senders with a good understanding can also clarify forensic science for others. For example, jury deliberation may provide an opportunity for more knowledgeable jurors to assist less knowledgeable jurors. However, it is unclear how commonly deliberation clarifies (or obscures) the meaning of forensic scientific evidence (Dartnall & Goodman-Delahunty, 2006; Koehler, 2011; McQuiston-Surrett & Saks, 2009; Smith, Bull, & Holliday, 2011).

The Message

Past research has shown forensic science in a trial context to be influential in conviction rates (Dartnall & Goodman-Delahunty, 2006; Koehler, 2011; McQuiston-Surrett & Saks, 2009; Smith, Bull, & Holliday, 2011). Thus, a great deal of research focusing on the message has been concerned with communicating the appropriate weight of the evidence. A major debate has centred on the issue of correctly communicating the significance of the evidence. The options presented have included the use of qualitative expressions of strength of association, or statistics (e.g., frequencies, probabilities, or likelihood ratios), or a combination of qualitative and statistical approaches. It has been argued that the logically correct way to present significance of evidence is by using likelihood ratios (Berger, 2010). On the other hand, some lawyers have argued that likelihood ratios are easily misunderstood by non-scientists and that estimated population frequencies are more appropriate for communicating the uncertainty of results to non-scientists (Ligertwood & Edmond, 2012).

The idea that meanings assigned to words can be communicated accurately from scientists to non-scientists was tested by McQuiston-Surrett and Saks (2008). The study showed that when meanings were assigned to expressions to indicate the strength of evidence by a scientific body, in this case the American Board of Forensic Odontology, mock jurors' understanding of the expressions differed markedly from what had been intended. For example, the term "reasonable scientific certainty" was the highest endorsement of an association that forensic odontologists could give, but was rated third of four terms provided, at 70.6% correspondence by mock jurors. To further complicate the language of reporting, research indicated that including the risk of error could lead jurors to undervalue the evidence in comparison with evidence that did not account for such risk (Koehler, 2011). Furthermore, evidence that provided only weak support for the prosecution case could be misinterpreted by mock jurors as providing support for the defence case (Martire, Kemp, Watkins, Sayle, & Newell, 2013).

Other studies that have explored the messages overall have considered which types of information should be included in forensic scientists' expert reports (Found & Edmond, 2012), the way that expert reports are currently presented by a range of laboratories and scientific disciplines (Siegel, King, & Reed, 2013), and the readability of conclusions (Howes, Kirkbride, Kelty, Julian, & Kemp, 2013) and expert reports (Howes, Julian, Kelty, Kemp, & Kirkbride, 2014; Howes, Kirkbride, et al., 2014). Overall, this research has documented various differences in approaches to reporting by jurisdiction and discipline and identified areas for potential improvement in terms of more complete and comprehensible content.

The Channel

Research on the channel of the message has considered whether the message is verbal or written, formal or informal. Forensic scientific findings are most commonly formally communicated via written reports in both adversarial (Rothwell, 2010) and inquisitorial (Broeders, 2003) legal systems. It seems that less formal, verbal interaction between scientists and non-scientists may be less common depending on case type. In research conducted in Australia, it was found that face-to-face meetings between police investigators and forensic scientists were routine in investigations of murder but not for other serious crimes, such as sexual assault, or for high-volume crimes (Kelty et al., 2013).

When an expert was required to testify as a witness during a trial, lawyers and forensic scientists had different perceptions of what constituted a pre-trial meeting. What lawyers perceived as a “pre-trial meeting”, scientists more likely viewed as a “brief chat” (Kelty et al., 2013). The short time allocated to pre-trial meetings by lawyers may be explained in part by issues such as a lack of time and budgetary constraints, for all lawyers, but for defence lawyers in particular (Cashman & Henning, 2012). On the other hand, research by Kelty et al. (2013) indicated that practitioners who regularly participated in practice improvement groups with a multi-disciplinary team in the criminal justice system had a better understanding of the various roles within the system. When questions or concerns arose about a specific case, the practitioners were able to contact a known person within the multidisciplinary system, and were more likely to be able to ask questions without embarrassment (Kelty et al., 2013). Thus, communication of a message in a formal channel, such as a report, may be supplemented at times by communication in an informal channel, such as a phone call.

Research examining the channel of communication of forensic science in the courtroom has compared how jurors' understanding varies across channels. Although the structure of courtroom discourse has been described as "rigid and asymmetrical" (Eades, 2012), alternative presentation formats are possible. When jurors were presented a PowerPoint tutorial in which information about DNA was carefully sequenced to build upon juror knowledge, comprehension scores were higher than when DNA was explained by traditional testimony alone (Goodman-Delahunty & Hewson, 2010). When the PowerPoint presentation was used, mock jurors learned more about DNA than did those who heard expert evidence without a PowerPoint presentation. Mock jurors who saw the PowerPoint presentation were less likely to think that DNA evidence was infallible and less knowledgeable jurors who viewed the PowerPoint presentation were less likely to convict than were those who had heard only verbal evidence, making their verdict decisions more similar to those of more knowledgeable jurors (Goodman-Delahunty & Hewson, 2010). Thus, it seems that the potential exists to enhance understanding of forensic science by carefully considering the channel/s of its delivery.

The Receiver

Research on receivers has considered the attributes of audiences (in particular, police investigators, lawyers, judges, and jurors), including prior knowledge of forensic science, education level and scientific literacy, TV viewing habits, decision-making approaches, attention given, and role in the criminal justice system. Research in the United States showed that police investigators did not always submit potentially relevant samples to forensic laboratories for testing (Strom & Hickman, 2010). In some instances, this was attributed to a lack of knowledge and understanding about forensic science. For example, at times, DNA samples were not submitted because a suspect in the case had not been identified (Strom & Hickman, 2010), yet it may have been possible to match a sample from the crime scene with a sample already registered on the DNA database.

Researchers asked lawyers about their experiences with understanding DNA evidence (Cashman & Henning, 2012). Responses indicated that lawyers found scientific principles and the scientific language difficult to understand and to synthesise. Lawyers' understanding of DNA evidence did not necessarily improve after encountering reports of DNA analysis in previous cases because lawyers approached DNA on the basis of the particular case-specific issues in each instance. Similarly, lawyers expressed that it was difficult to apply information from workshops of a general nature to specific cases at a later date (Cashman & Henning, 2012).

A survey was conducted with members of the Australian judiciary and over 50% (n = 244) of the 478 judges responded (Freckelton, Reddy, & Selby, 1999). It was found that 70% of the participating judges reported having heard expert evidence in trials, which they had not understood (Freckelton et al., 1999). Approximately 20% of judges reported that they often found it difficult to evaluate differing expert opinions introduced by the parties (Freckelton et al., 1999).

A Dutch study compared the actual and self-assessed comprehension of verbal and visual equivalents to likelihood ratios by judges, defence lawyers, and forensic practitioners. The likelihood ratio equivalents were used to express expert opinion regarding chemical signature of glue residue and comparison of security camera images in two fictitious reports (De Keijser & Elffers, 2012). Forensic practitioners outperformed judges and defence lawyers on comprehension tasks, but all groups rated their understanding higher than could be justified by the results. Many errors in comprehension, even amongst forensic scientists, were attributable to the prosecutor's fallacy[3], with errors in defence attorney's fallacy more common amongst defence lawyers than others. Further analysis revealed that lawyers and judges who had participated in additional training did not demonstrate superior comprehension of likelihood ratio expressions. De Keijser and Elffers (2012) noted that as long as lawyers and judges lacked awareness of their gaps in comprehension, there would be little incentive to improve understanding.

Amongst jury eligible people, appropriately weighing DNA evidence was related to a greater understanding of that evidence (Goodman-Delahunty & Hewson, 2010). Studies have associated greater comprehension of scientific evidence with greater scientific literacy achieved through higher educational attainment and more education in mathematics and science (Hans, Kaye, Dunn, Farley, & Albertson, 2011). Although the understanding of scientific evidence was incomplete amongst jury-eligible people, most of them could weigh the evidence and apply it to fact-finding roles (Hans et al., 2011). However, whilst jury-eligible people were able to weigh evidence accurately in the absence of a case context, they tended to overweigh the evidence in the context of a criminal case (Smith et al., 2011).

Feedback

Research in this category might include scientists' observations or perceptions of verbal and non-verbal feedback from receivers of communication about forensic science. Feedback in the system can also be seen in juror expectations of scientific evidence influencing the system. For example, lawyers for the prosecution may need to call

[3] Both the prosecutor's and the defence attorney's fallacies refer to errors in statistical reasoning – that favour the prosecution or defence respectively.

scientists to explain to jurors the reasons for a lack of forensic scientific evidence in some cases (Shelton et al., 2006).

Noise

Noise can be described as any information extraneous to the forensic science itself, which has a bearing on how the forensic science is understood in the case context. This could include issues such as the duration of a trial or the time of day that forensic science was presented to the jury. It could also include aspects permitted by the legal system, such as directions to the jury to ignore certain pieces of evidence (Edmond, 2011) or permitting so-called experts to testify on techniques that have not been scientifically validated, which has impeded the justice process in a number of past cases (Edmond, 2014).

Notwithstanding the issue of unequal access to experts for the defence (Edmond, 2014; Findley, 2008), it is also possible for noise to be introduced when an expert is called to cast doubt upon the scientific evidence introduced by the prosecution. An expert is generally defined as someone who has relevant qualifications and experience, rather than an expert within the field from which they come (Edmond, 2014). Scientists who do not concur with the majority could equally be called and admitted by the courts as expert witnesses. This scenario presents the alternative view as an opposing position in a debate, similar to media reporting of science using an expert controversy (Peters, 2008) or uncertainty debate as a frame (e.g., climate change). Further complications may arise in that although scientists' duty is to the court, the veracity or completeness of the opinion presented may be called into question in light of partisan influence, especially in regard to payment for that opinion.[4] Given that one-fifth of judges reported difficulty in evaluating different expert opinions (Freckelton et al., 1999), the practice of representing alternative interpretations of science, as though equally plausible, despite the existence of scientific consensus on one

[4] Thank you to an anonymous reviewer for suggesting that this point be included.

side, could result in unnecessary additional confusion for judges and jurors about the weight of evidence.

4. Rationale for Future Research on Communication of Forensic Science

For each of the communication components (sender, message, channel, and receiver), some limitations of research to date are outlined below and suggestions for further research presented.

The Sender

Limited past research has taken into account the perspectives of scientists. However, existing studies suggest that scientists would welcome further opportunities to clarify their findings (e.g., with lawyers; Wheate, 2008) so that they can be used effectively. Further research is needed to determine scientists' perceptions about what would constitute adequate opportunities to communicate their findings in the criminal justice system to assist in directing police investigations and legal processing of cases. Further research is also needed to determine scientists' communication training needs, to ensure that they are well-equipped to communicate complex concepts effectively, while retaining the necessary degree of scientific precision.

The Message

Research on the message has tended to present information about scientific findings in summary form only (Koehler, 2011; McQuiston-Surrett & Saks, 2009) with differing amounts of contextual information. In these studies, features of real trials that are often missing include *voir dire*, opening statements, live witnesses, objections, detailed judicial instructions, and deliberations with fellow jurors. This limits the amount of contextual information that jurors can use to assist in understanding the forensic science, and also the generalizability of such studies to real case contexts.

Furthermore, research on the message component has focussed on the wording of forensic scientists' expert opinions, sometimes in the absence of case context (McQuiston-Surrett & Saks, 2008). Past research has been concerned with how best to communicate uncertainty and whether statistical or qualitative terms or a combination thereof are more successful in communicating the appropriate weight of evidence in a given case. This research is important to consider especially in light of calls to standardise terminology used in reports and courtroom testimony. However, because meaning is not inherent in words, but must be negotiated and co-constructed between sender and receiver or constructed by the receiver of the message (depending upon the channel of its delivery), future research that aims to retain the message in more than a summary form is also needed.

The Channel

Researchers have overwhelmingly focussed on the formal context of expert testimony in the courts, leaving a comparable dearth of research about written communication (e.g., expert reports and statements), despite their more ubiquitous use in communicating findings. Less formal, but potentially influential forensic science communication contexts, such as telephone calls, email exchanges, and face-to-face meetings, have also attracted less research attention. It would be worthwhile to pursue research that is able to determine the significance of various channels in communicating effectively about forensic science. Research is needed to determine different jurisdictions' approaches to communicating effectively (e.g., with policing organisations to provide forensic intelligence) in light of concerns about contextual bias (Kassin et al., 2013).

The Receiver

A number of limitations have been noted in past research with jurors. Because jury decision-making is generally off limits to researchers, participants have often included mock jurors comprised of university students whose characteristics (e.g., age and education), may not reflect the composition of real juries, nor may the tensions and pressures involved in reaching a decision be realistic. In other studies, the limitation has been addressed by obtaining a sample of jury-eligible people who are members of the general public (Goodman-Delahunty & Hewson, 2010; Smith et al., 2011). It is anticipated that a large-scale research project, in which permission was obtained to survey and interview jurors (as well as judges, lawyers, and experts) from a number of trials, will help to address some methodological limitations inherent in past research and clarify a number of aspects of juror comprehension of expert evidence[5].

A further limitation of studies of receivers, however, is that compared with jury studies, relatively fewer studies have examined how well police investigators, lawyers, and judges understand the forensic science that they use in their roles. Research exploring these practitioners' understanding of forensic science, their information needs, and their communication preferences is warranted (and is not prevented by the constraints applicable to jury research). More research on decision-making approaches of receivers (including jurors) may help to clarify the appropriate level of specificity needed in the communication of forensic science.

Conclusion

Overall, although contemporary views of communication and science communication recognise the importance of the construction of shared meaning, the approach to communication of forensic science can be seen as mostly conforming to a deficit model of science communication. As such, it was proposed that a transmission model of communication, modified to incorporate the social and legal contexts in which it occurs,

[5] Thank you to an anonymous reviewer for this point. For further information about the project see Expert Evidence and Criminal Jury Trials at the University of Melbourne website: http://www.law.unimelb.edu.au/melbourne-law-school/research-and-expertise/expert-evidence-and-criminal-jury-trials

and consideration of the level of interaction possible, could be used to represent the communication of forensic science in the criminal justice system. This conceptual model was used to organise examples of existing research and legal commentary on the communication of forensic science. The resulting brief overview of research highlighted some of the complexity associated with achieving effective communication of forensic science in this multidisciplinary arena. Past research has tended to be dominated by studies examining aspects of delivering expert evidence in court and juror comprehension of such evidence. Aspects of communication to be addressed more fully in future research include examining the effectiveness of the communication for police, lawyers, and judges; identifying the extent to which formal communication to practitioners is supplemented by less formal communication; and incorporating scientists' and non-scientists' perspectives to facilitate clearer communication of forensic science within the criminal justice system. Given the constraints of the legal system and the complexity of forensic science, more work is needed before the communication of forensic science can be considered optimal. However, extant research and commentary on the communication of forensic science provides a sound foundation for further development towards this goal.

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3

Developing the Methodology for an Applied, Interdisciplinary Research Project: Documenting the Journey towards Philosophical Clarity

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Abstract

Methodologists have urged researchers who use mixed methods to justify their methodological choices, and provide greater clarity about the philosophical underpinnings and implications of their approaches. This paper outlines the reasoning process undertaken in an endeavour to develop philosophical clarity for an applied, interdisciplinary, mixed-methods research project about the communication of scientific evidence in the legal system. I used Greene's (2006) domains of methodology for social inquiry as a framework for addressing reflexive questions about assumptions. Flowing from the domains of values and philosophies, the logic of inquiry was developed before the implications for the integration of findings and reporting of research were outlined. Early engagement in reflexive questioning provided a foundation for methodological refinement throughout the ongoing research journey.

Developing the Methodology for an Applied, Interdisciplinary Research Project: Documenting the Journey towards Philosophical Clarity

Methodologists have urged social researchers to fully explicate their methodologies (Alise & Teddlie, 2010; Harrits, 2011; Hesse-Biber, 2010), and to share their thinking processes as they engage in research (Greene, 2008). Explaining methodology and the reasoning behind it both contributes to debates central to the development of the field of mixed-methods research (Teddlie & Tashakkori, 2011), and responds to the criticism that mixed-methods research has been inadequately justified in the past (Harrits, 2011; Hesse-Biber, 2010). The purpose of this paper is to respond to methodologists' calls for philosophical clarity and to provide an example of the thought processes behind the development of the methodology for a mixed-methods research project.

Methodology is complex. It is distinct from the *methods* as specific procedures or techniques for data generation (Mason, 2002) and yet comprises these. Methodology also encompasses "the analysis of the principles or procedures of inquiry" ("Methodology", 2015), and is intertwined with the philosophical considerations of ontology (the nature of reality), and epistemology (the nature of knowledge; Guba & Lincoln, 1994).

Although methodologists differ on the extent to which they see the philosophical elements as bound together, many methodologists concur that ontology, epistemology, and methodology together constitute an inquiry paradigm (Guba & Lincoln, 1994; Lincoln & Guba, 2011), or philosophical stance (Greene, 2006). This philosophical stance, with its origins in metaphysics and logic, is further informed by other branches of philosophy (such as ethics and aesthetics). Axiology (the nature of valuing, value judgments, or ethics) influences the nature and conduct of the research, which may be reflected ultimately in rhetoric (the language of research; Lincoln & Guba, 2011; Sandelowski, 2003).

Alise and Teddlie (2010) argued that because philosophy and methodology are intertwined, it is not possible to explicate methodology without philosophical clarity. Philosophical clarity assists researchers in replicating studies, and readers in assessing the quality of interpretations. Indeed, the need to make explicit the philosophical stance may be particularly pressing in applied research, because mixed-methods approaches have not tended to be dominated by any one philosophical stance (Alise & Teddlie, 2010). It has been argued that without philosophical clarity, not only may it be unclear to readers which philosophical stance was adopted by researchers (Alise & Teddlie, 2010), but also whether the stance was adopted explicitly or implicitly, outside researcher awareness (Hesse-Biber, 2010).

To achieve philosophical clarity, researcher reflexivity, or critical thinking by researchers about their own assumptions, is essential (Hesse-Biber, 2010; Mason, 2002). The process of developing methodological clarity is ongoing, and requires that researchers ask “difficult questions” throughout the life of a research project (Mason, 2002, p. 4). A useful framework for the necessary reflexivity about assumptions and issues in a given research project was provided by Greene (2006). Greene’s conceptualization of a methodology for social inquiry consisted of four broad and interlinked domains. These domains address both the philosophical issues and assumptions of Guba and Lincoln’s (1994) inquiry paradigm, as well as broader and more general considerations. The domains are:

(1) philosophical stances and assumptions (including ontology and epistemology);

(2) inquiry logics (often known as methodology);

(3) guidelines for practice (specific procedures or methods); and

(4) socio-political commitments (location of the research in society, axiology or values, and ethics).

Achieving philosophical clarity entails reflexive questioning in all domains (Alise & Teddlie, 2010; Harrits, 2011).

Crotty (1998) suggested working from the more concrete methods (Domain 3) to the more abstract theoretical and epistemological stances (Domains 1 and 2). In contrast, a methods-centric approach, which has been described as a “cart before the horse” approach (Hesse-Biber, 2010, p. 11), would start and finish in the domain of practical guidelines (Domain 3) and address inadequately (if at all) the domains of philosophical stances and assumptions, inquiry logic, and socio-political commitments. Throughout the program of research undertaken for my PhD, I found the process of working towards philosophical clarity to be recursive; it required considering and later returning to different methodological domains, moving back and forth through them. This was because a decision in one domain had potential implications in other domains. With an ongoing and recursive process, one could start in any domain, provided that all domains were adequately addressed.

This paper presents an example of working towards philosophical clarity, using Greene’s (2006) domains, for my PhD research on the effectiveness of interdisciplinary communication about forensic science in the criminal justice system. It may be viewed as a work-in-progress in the sense that my journey as a researcher is ongoing and I expect my philosophical stance to continue to evolve. I do not address all aspects of the research domains, nor do I address them in equal depth; I necessarily consider the issues of most concern to me as a researcher in the context of this project, namely developing the overall philosophical stance, valuing the perspectives of stakeholders, integrating the findings of different studies, and communicating the findings in writing. Although the process involved moving between domains, as far as possible, I discuss each domain in turn. I begin by discussing Greene's fourth domain, socio-political commitments, to provide context for the reader.

Socio-Political Commitments (Domain 4)

In this domain, "the location of the inquiry within society is articulated and defended" (Greene, 2006, p. 94), and values and meanings for the research are provided. Thus, the domain includes axiology, the ethical considerations mandated to meet institutional requirements, considerations of politics and power (Mertens, 2010), and value judgments of the researcher in the research process (Ponterotto, 2005).

Location of the Inquiry in Society

My research aimed to enhance the effectiveness of the communication about forensic science within the criminal justice system. Forensic science has been used increasingly over recent years in criminal investigations and trials (Smith, Bull, & Holliday, 2011). Miscommunication and ineffective communication of forensic science can result in miscarriages of justice (Garrett & Neufeld, 2009). Despite the small proportion of cases that culminate in a trial, relatively few of which are jury trials (Blumenthal, 2002), past research has focused on the use of forensic science in jury trials. The aim of this three-and-a-half-year project was twofold. First, it aimed to understand current approaches to the communication between forensic scientists and the professional groups (namely, police detectives, lawyers, and judges) who use forensic scientific findings in their roles. Second, it aimed to develop recommendations to enhance the effectiveness of such communication.

This research project was undertaken with the support of the Australian Federal Police, and met institutional ethical requirements. The research area is part of a growing body of psychological, social sciences, and interdisciplinary research about a multidisciplinary arena – the intersection of science and law (Blumenthal, 2002). It is applied research in that it addresses a specific issue with practical application as its goal (Dantziker & Hunter, 2012); it is interdisciplinary in that it draws from psychology, law, linguistics, sociology of science, and forensic science.

Politics and Power

Politics and power play an important role in this domain and involve considering the participants in – and the beneficiaries of – the research (Mertens, 2010). For example, the research may benefit forensic science service providers and forensic scientists, if it contributes to the status of the profession, perceived value of forensic science in the criminal justice system, and associated allocation of limited public funds.[1]

Research driven by values includes research conducted within a transformative paradigm, which specifically involves working with people who have been marginalized in some way, to address social justice and human rights (Mertons, 2010). Such research typically prioritises values-based considerations before turning to other methodological domains. While ultimately, my research may benefit people working within the criminal justice system, the wider community, victims of crime, and wrongly accused people, it must be acknowledged that I did not address directly the perspectives of people, who may have been affected by the ways in which forensic science is communicated. Instead, the aim was to seek the perspectives of practitioners working in the criminal justice system, such as police detectives, lawyers, and judges.

Although this project is not located within a transformative paradigm, it nevertheless seems appropriate to begin from the domain of socio-political commitments because the project is an industry-sponsored applied research project. Starting from the domain of socio-political commitments and values provides the context of the study and the opportunity to consider stakeholder influence and research input from the outset. Project stakeholders may have an influence on the formulation of the research questions (Hesse-

[1] Thank you to Associate Professor Roberta Julian for this point.

Biber, 2010); however, the Australian Federal Police were involved in the broad selection of the topic (rather than formulation of specific research questions). The provision of support from the Australian Federal Police indicates a relationship with implicit mutual responsibilities, for example, that the research address an issue of relevance, and that research progress and outcomes be communicated at regular intervals, to the organisation. For their part, in addition to some funding support, the Australian Federal Police agreed to facilitate the research through allowing access to participants.

Researcher Value Judgments

Considerations of the values that a researcher brings to the research can be addressed, in part, through researcher reflexivity (Hesse-Biber, 2010). I came to the research as an outsider to each of the professional groups represented (police, lawyers, judges, and forensic scientists), instead having professional experience in education, as a teacher of languages with a more recent honours degree in psychology. I anticipated a relationship with research participants of mutual respect between people from different professions, each with valuable experience and expertise. Such a relationship was of high importance to me in the conduct of the research. To be consistent with these stated values, my philosophical approach needed to take into account the different approaches to understanding and explaining the world, reflected in the epistemological positions of each of the key groups and individuals represented in my research (police, lawyers, judges, and forensic scientists).

Philosophical Assumptions and Stances (Domain 1)

The domain of philosophical assumptions and stances guides and justifies the way that the researcher sees what is seen. It encompasses not only ontology and epistemology, but also the values and perspectives (e.g., "core constructs of particular disciplines") held by the researcher (Greene, 2006, p. 93).

Theoretical Lens

Part of what informs researcher perspectives is theoretical considerations (as distinct from philosophical considerations), which may also be relevant to the research project. For example, Creswell and Plano Clark (2011) noted that the research project may be viewed through the lens of a psychological or a social science theory. Such theory guides the nature of questions asked and answered in a study (Creswell & Plano Clark, 2011). The theoretical perspectives that were relevant to my research address the ways in which meaning is constructed and communicated through (scientific and legal) discourses. Relevant theoretical perspectives included broad theories of human communication and science communication, as well as more specific theories that could be used to explore the nature of the communication between scientists and non-scientists.

The dominant paradigm used to describe science communication has been one of knowledge transfer (Bucchi, 2008); this is consistent with a transmission model of communication initially proposed in the context of telecommunications (Shannon & Weaver, 1949). Essentially, the transmission model reflects a deficit or dissemination approach to communication, assuming that the scientist is a repository of knowledge and can transfer that same knowledge to the audience. However, alternative models of science communication such as the dialogue (transaction), and participation models (Bucchi, 2008), recognised the importance of interaction between the parties to the communication to negotiate shared meanings. Such interactive views of science communication reflect the approaches adopted by many contemporary communication scholars (Campos, 2007) and accord with a constructivist paradigm.

When limited opportunity exists for interaction, such as in these instances of communication by experts in the criminal justice system, the transmission model may offer a useful heuristic (Craig, 1999; Dixon & Bortolussi, 2001). Therefore, the transmission model has relevance to my research because of the constraints on communication that are inherent in the criminal justice system (e.g., written reports form the basis of the communication; Rothwell, 2010; and jurors and judges listen to testimony rather than interact with scientists). However, while the transmission model assumes that what is written and what is read are one and the same, constructivist accounts of reading emphasise the interaction of the reader and the text to make meaning (see Crotty, 1998). Readers do not passively absorb the information they read, but bring their interpretations to bear in what has been described as the interaction between the reader and the text. Influenced by my experience of studying and teaching languages, and the broad and inclusive approach taken by sociolinguists Halliday and Martin (1993) in their study of scientific language, I adopted a more holistic approach to communication that includes its context, in accordance with constructivist views.

Ontology

Ontology is about the essence of the social world and the nature of reality and is often implicitly understood; therefore, it may be difficult to make explicit an ontological standpoint (Mason, 2002). Mason (2002) provided a list of ontological properties, as a starting point to identifying the nature of social reality from any given ontological position. This list included people, understandings, interpretations, social processes, groups, and institutions (see Mason, 2002, p. 15). In order to reveal and clarify the ontological assumptions about the nature of reality guiding my research, I used Mason's list and the working title of my research project (which was provided to me at the outset of the project) – "Communicating expert opinion: What do forensic scientists say and what do police, lawyers, and judges hear?"

The working title alluded to a social reality containing distinct and particular groups of people (forensic scientists, police, lawyers, and judges); a particular type of opinion (expert); and the act of communicating as a dichotomous action, divided into “say” and “hear”. The notion of “expert opinion” expressed as a singular (rather than plural) concept, suggested a single, objective reality. This objective reality is consistent with positivism, wherein reality is seen to be directly observable by a value-free researcher. More specifically, post-positivism, assumes that reality exists, and although it is imperfectly understood (Guba & Lincoln, 1994), it can be approached via the perceptions of research participants.

Conversely, the presence of a number of professional groups (forensic scientists, police, lawyers, and judges) suggested multiple perspectives and subjectivities. In fact, expert opinion is also multiple, in the sense that many forensic scientific disciplines exist, individual scientists within a discipline may differ in their interpretation of results, and separate expert witnesses from the same scientific discipline may be called by the prosecution and defence in a criminal trial. This subjective reality is consistent with constructivism and relativism, wherein reality is socially and experientially based, local and specific in nature (Guba & Lincoln, 1994).

The assumption implicit in the dichotomous notion of communication, with listeners and speakers represented is that the perspectives of the different groups who “say” or “hear” the communication can or do differ, consistent with a constructivist stance. Whilst I acknowledge that alternative interpretations are possible, the purpose of reflexive questioning is to identify the researcher’s own assumptions. The ontological properties of the social reality suggested by the research topic lead on to epistemology.

Epistemology

Epistemology includes considerations about whether something can be known about the (identified) ontological properties of the social world, how it can be known, and how such knowledge can be demonstrated (Mason, 2002). According to Mason (2002), the credibility of an epistemological stance may vary with academic discipline, and the research paradigm may vary with epistemology.

The implication of my ontological position for epistemology, is that it is possible to know both a single objective reality (of the communication of expert opinion) and subjective multiple perspectives of this communication. The overarching goal of research interactions with practitioners was not, however, to know objectively about the communication of expert opinion in the criminal justice system as an observer or outsider (as would be the goal of a post-positivist approach, Guba & Lincoln, 1994). Rather, the goal was to negotiate shared understandings of the communication of expert opinion, through interactions with participants, and to bring my interpretations of these interactions to the research, in light of the social science theory or theories employed. Thus, there are both realist and constructivist elements to my epistemological position, but the dominant element is constructivist.

The ontological and epistemological positions I have expressed are consistent with each other in that both contain elements of constructivist and post-positivist paradigms. On the other hand, the forensic scientists within the Australian Federal Police who contribute to the project may be accustomed to a positivist or post-positivist approach to research. Differences in stakeholder worldviews are not uncommon in applied and interdisciplinary research, and this is one justification for mixed methods approaches (Hesse-Biber, 2010).

Researcher Perspectives

Researcher expertise and resources are important considerations in selecting an approach (Creswell & Plano Clark, 2011; Hesse-Biber, 2010). I have undertaken undergraduate and postgraduate courses in both quantitative and qualitative research paradigms and have drawn on that knowledge in past conduct of mixed-methods research. Members of the research team (supervisory panel) for this project have extensive experience in qualitative, quantitative, and mixed-methods approaches, being drawn from the social sciences, psychology, and forensic science. Thus, the possibility existed to use any one of these approaches. I consider this issue in more depth under the domains of inquiry logics and guidelines for practice.

In interdisciplinary research contexts, from the domain of socio-political commitments, it is essential to value different ways of knowing and understanding the world (Petrie, 1976), and this was one of my primary concerns. A constructivist-dominant approach seems to offer this inherently. However, the logic behind such an approach needs to be articulated. If a constructivist, post-positivist, or some form of combined philosophical stance is adopted, it remains to explore the methodological domain of inquiry logic to determine whether and how such an approach makes logical sense.

Inquiry Logics (Domain 2)

This domain encompasses what is often referred to as methodology and covers inquiry strategies and designs, sampling preferences and logic, criteria of quality and inference, and defensible forms of writing and reporting (Greene, 2006). Many of the issues discussed in this domain overlap with those in the domain of Guidelines for Practice, and are revisited in that domain.

Inquiry Strategy (Research Paradigm)

Deciding on a research paradigm or inquiry strategy involves considering the logical implications of one choice over another and moving back to philosophy to assess the fit. Mixed-methods research has been described as "the type of research in which a researcher combines elements of qualitative and quantitative research approaches" (Johnson, Onwuegbuzie, & Turner, 2007, p. 123). The term *mixed research*, as opposed to mixed-methods research, has been used to emphasise that the mixing may be at levels other than use of quantitative and qualitative data sets. Mixing can occur, for example, in philosophical stances, data collection, analysis, and inference techniques (Johnson et al., 2007). Thus, in this view, mixed research could potentially involve a programme of study in which all studies were qualitative.

Discussions about how to justify the mixing of methods at the philosophical level have been ongoing since the 1980s (Creswell & Plano Clark, 2011) and are the subject of current debate (Teddlie & Tashakkori, 2011). Mixed-methods researchers have been criticized, however, for the wholesale adoption of a particular stance (a pragmatic stance) without adequate justification (Harrits, 2011; Maxwell, 2011). Furthermore, although mixed-methods research can be conducted within any philosophical paradigm (Giddings & Grant, 2006; Guba & Lincoln, 1994), some methodologists viewed the approaches to mixed-methods research as a new guise for post-positivist approaches, with constructivist approaches playing subsidiary roles (Giddings & Grant, 2007). In short, a homogeneous approach to mixed-methods research has been deemed inadequate because the justification and practice of mixed-methods research differs at a philosophical level (Harrits, 2011).

Four approaches to resolving the issue of mixing research paradigms were proposed by Greene and Caracelli (2003): dialectic, new paradigm, pragmatic (or context-driven), and concept-driven approaches. Dialectical pluralism held that use of multiple paradigms would lead to better understandings. Newer paradigms, such as constructivist realism (Cupchik, 2001), and critical realism (Maxwell & Mittapalli, 2010) viewed both quantitative and qualitative research paradigms as complementary, rather than incompatible. Pragmatic paradigms were positioned as perspectives capable of unifying researchers from different traditions (Johnson & Onwuegbuzie, 2004) and turning the focus from philosophical to practical issues (e.g., Morgan, 2007), to respond to the demands of the context of inquiry. Concept-driven approaches prioritized conceptual or theoretical congruence. Currently, according to Teddlie and Tashakkori (2011), the most widely accepted philosophical approaches are pragmatism (in various conceptualizations); transformative approaches (where values guide other philosophical considerations); and the dialectical stance.

It seemed possible that my research project could be done within a pragmatic paradigm. A pragmatic approach would not commit me to one particular philosophy, yet would allow me the freedom to respond flexibly to the practical demands of inquiry to produce socially useful knowledge (Feilzer, 2010), as is important in the context of applied research. Such an approach would allow me to engage inquiry logic that would best address my research questions, in contrast to approaches tied to particular theoretical perspectives, which may be seen to constrain or limit researchers' imaginations (Feilzer, 2010).

Perhaps a concept-driven or coherentist approach would be possible. As discussed under the theoretical lens, a constructivist view of communication informed the theoretical stance. This aligned with the intention for the conduct of research to take a constructivist approach to negotiate meaning with interview participants. However, the project was not restricted to constructivist studies and did not rule out alternative theoretical approaches to the study of communication.

On the other hand, it also seemed that dialectical pluralism may be appropriate for my work. I established in the section on socio-political commitments that my research was not conducted within a transformative paradigm, although stakeholder input was high in importance. Dialectical pluralism recognises the differences inherent in the respective philosophical stances (Maxwell, 2011), and draws on these differing philosophical approaches, resulting in multiple stances – multiple ontologies, epistemologies, values, and methods – within the one project, subsumed under a meta-paradigm (Greene & Caracelli, 2003; Johnson, 2011, 2012). The key assumption of dialectical pluralism is that dialogue between diverse perspectives on the research issue will deepen understandings gained on complex issues (Maxwell, 2011) and broaden their acceptance (Johnson, 2011), which is an important consideration in interdisciplinary research.

Overall, the common element between all of the meta-paradigms for mixed-methods research is the valuing of different approaches in addressing complex questions. At the risk of over-simplifying, it seemed to me that researchers' chosen meta-paradigms arose from their critical reflections on the reasons why a mixed-methods approach was adopted. If a mixed-methods approach was selected primarily with the goal of addressing research questions effectively, the overarching approach was more likely to be pragmatic. If a mixed-methods approach was selected to deliberately incorporate a variety of perspectives, it was more likely to come from a stance of dialectical pluralism.

In reviewing past research on the communication of expert evidence in the criminal justice system (Howes, 2015a), it seemed to me that it had been predominantly conducted within a post-positivist paradigm. My purpose for conceptualising the research project as a mixed-methods one was mainly to value the diverse perspectives of participant groups and approaches, in terms of philosophy, logic, and techniques. The approach I planned was not simply a post-positivist approach, with a small role for a constructivist approach, but the other way around: The constructivist element was to be dominant, to ensure that different participant perspectives were heard. At the same time, I recognised the importance, familiarity, and appeal to forensic scientists of approaches from the (post-)positivist tradition, and wanted to ensure that those were valued in my approach as well.

To return to the question, posed in the domain of philosophical assumptions and issues, of whether and how a constructivist stance was logical: A philosophical stance incorporating constructivism and post-positivism made sense to me as a researcher, and made sense for this research project, under a meta-paradigm of dialectical pluralism (Johnson, 2012).

Research / Inquiry Design

It would not be appropriate to start by deciding upon a research strategy of mixed methods if this approach were not suited to answering the research questions (Greene, 2008). The philosophical stance (dialectical pluralism) informs the research strategy and links research questions to methods of inquiry. Dialectical pluralism as a (personal) meta-paradigm leaves open the possibility for constructivist or post-positivist approaches, or both in combination, and in consultation with other members of the research team and project stakeholders.

My overarching research question asked: “How can forensic scientists’ current reporting practices be modified to enhance the effectiveness of communication?” I identified five subsidiary research questions to address parts of the larger question, of which some could be answered by qualitative, some quantitative, and some by qualitative and quantitative methods. My subsidiary questions were:

(1) How do forensic scientists currently communicate their findings to the police, lawyers, and judges?

(2) How effective do forensic scientists, police, lawyers, and judges perceive the communication to be?

(3) What communication features help police, lawyers, and judges to use forensic scientists’ findings effectively in their roles?

(4) How well are forensic scientists’ written reports understood by report-users? and

(5) What modifications to reporting best meet the needs of report-writers and report-users?

Mason (2002) suggested that once research questions have been identified, potential associated methods of inquiry, and the justifications for these should be considered in order to determine the most compatible approach. To illustrate potential data sources and their justifications, I use the first of my questions, as it provides a mixed-methods example.

The first research question was: “How do forensic scientists currently communicate their findings to the police, lawyers, and judges?” Potential data sources and methods used to respond to this question included interviews with forensic scientists and members of each of the professional groups, and analysis of samples of expert reports. The justification for interviewing different professional groups was to provide situated knowledge, a range of accounts and relevant experiences about expert evidence, whether presented formally or informally, and whether in verbal or written forms. The interviews reflected a (primarily) constructivist approach. The justification for analysis of expert reports was that they would reveal something about how expert opinion was presented using formal written language and conventions. The document analyses involved mixing at the paradigm level, with post-positivist and constructivist elements, and at the level of data analysis with quantitative and qualitative elements.

The foregoing example showed that a mixed approach was justifiable in terms of the research questions. The questions reflected the twofold purpose of this research project: to explore the effectiveness of current communication practices and to recommend some modifications designed to enhance the effectiveness of communication. Limited past research on the nature of forensic scientists’ expert reports and on the communication needs of scientific report-writers and -users (including police, lawyers, and judges) gave the project an exploratory focus. Exploratory programs of research typically give emphasis to qualitative-dominant approaches (Creswell, Shope, Plano Clark, & Green, 2006). Such approaches may provide a broader lens through which to look at complex research issues in interdisciplinary contexts (Hesse-Biber, 2010). Although (quantitative) testing of recommendations (e.g., subsidiary research question 5) was beyond the scope of this research project, further studies to test and validate recommendations are planned as a follow-up to the project.

Integration

A central issue in the integration of results of mixed studies has concerned the idea of incommensurability between different philosophical paradigms. Indeed, Harrits (2011) argued that different perspectives may produce different results and that any such divergent results must be handled with extreme rigor. As noted earlier, however, proponents of a meta-paradigm of dialectical pluralism not only recognise the possibility of using different philosophical stances in research designs, but regard the tensions and dialogues between different views as valuable means to address research questions most completely (Maxwell, 2011). Even so, the ways in which data from different methods within the mixed-methods study are integrated are a central aspect of the evaluation of the quality and trustworthiness of the research.

Mason (2002) suggested that different methods could be integrated at the following levels:

(1) technical (may be possible if units of analysis are consistent),
(2) ontological (may be possible if based on similar assumptions about the nature of social entities),
(3) epistemological and evidential (may be possible if the data are comparable or complementary), or
(4) explanatory (may be possible if the data contribute to a coherent and convincing argument).

Under a meta-paradigm of dialectical pluralism, studies conducted under the different philosophical stances each contribute partial knowledge on the broader research issue. Therefore, logically, integration at the third level (of knowledge and evidence) and fourth level (of explanation) are perhaps most appropriate. I return to my approach to integration in the domain of guidelines for practice.

Writing and Reporting

Given that my project is about the effectiveness of the communication of forensic science, the issue of communicating my own research effectively to various stakeholder groups was of great importance to me. Considerations of rhetoric and representation are essential to justifying decisions about writing and reporting. Rhetoric is about the effective use of language and discursive strategies for persuasion (Sandelowski, 2003). Considerations include writing conventions, prescribed styles, purposes, audiences, and researcher preferences. Representation is the use of strategies (linguistic, visual, or other) to represent or portray persons, objects, or experience (Sandelowski, 2003). Representation includes the issue of conveying respect for the groups and individuals who participated in the research project through the use of non-biased language and accurate reflection of the views expressed.[2] In addition, because the research project was interdisciplinary, conveying respect for the reader includes providing definitions of discipline-specific terms (Greene, 2007). For mixed-methods researchers, representation involves presenting the research itself in ways which are respectful of the qualitative and quantitative research paradigms and the readers from those traditions (Sandelowski, 2003).

The conventions for presenting research conducted under post-positivist and constructivist paradigms can differ in key ways. For example, post-positivist research tends to employ the use of the third person, presenting findings from the standpoint of an

[2] I offered each interview participant a copy of their transcript and the opportunity to make amendments; policing organisations and forensic scientific laboratories were provided with drafts of the papers reporting the studies prior to their publication.

objective observer of fact, and often adheres to strict conventions. Conversely, qualitative research conducted under a constructivist paradigm may be written in the first person, detailing subjective perceptions of the researcher (Ponterotto, 2005), and occurs along a continuum, with many styles possible (Ellingson, 2011). Furthermore, the post-positivist notion of reporting research has been construed as “writing-up” at the conclusion of the process. In contrast, the constructivist notion has been construed as “writing through” the research process; writing is viewed as “indistinguishable from analysis and interpretation” (Sandelowski, 2003, p. 330).

To address the issue of reporting mixed-methods research, Onwuegbuzie and Johnson (2006) suggested two solutions to paradigmatic mixing: (1) the use of two styles – a dualist position, and (2) the use of moderate versions – a continuum position. Although the dualist position may have implications for the way the report flows (Leech, 2012), switching from a more “informal” style to a more “formal” writing style, this is the approach most suited to a stance of dialectical pluralism. This dualist position is advocated by a number of mixed research methodologists. For example, Greene (2007) argued for mixing voice and language in mixed-methods writing, suggesting that this indicated good practice in mixed research. Leech (2012) suggested that in practical terms, the different styles could be used following natural breaks in sections or chapters and encouraged researchers to view the current lack of prescribed approach to reporting mixed-methods research as an opportunity to demonstrate creativity. I return to the specific issue of writing style in the domain of guidelines for practice.

Guidelines for Practice (Domain 3)

This domain offers specific guidelines, steps and procedures, which flow from philosophy and logic outlined in Domains 1 and 2. These are the specific methods or the “how to” for inquiry design, sampling, gathering data, analysis, interpretation, and reporting (Greene, 2006, p. 94). The issues discussed in this domain overlap in part with the domain of inquiry logic. I outline briefly the methods for the project here, as more detailed accounts are presented in papers reporting the results of the studies. I then refer to two sections from inquiry logic – namely, integration, and writing and reporting, to outline the implications of philosophy for practice.

Gathering Data (Methods)

The considerations and steps of this domain are generally described in methods sections of research reports. Guidelines for practice are familiar territory when thinking about methodology, and are particular to individual research projects. In this case, Part 1 of the project involved both qualitative and quantitative content analysis of written reports (of forensic biology and forensic chemistry).[3] Part 2 involved semi-structured interviews with forensic biologists and trace evidence examiners (who report on DNA and forensic glass examination respectively), and police detectives, lawyers and judges (who use forensic scientific findings in their work). Although I initially intended to incorporate Part 3 in which I would test the recommendations (Creswell & Plano Clark, 2011), during the project, it became evident that allocating time in Parts 1 and 2 to an Australia-wide research endeavour was the most pressing issue, whereas the testing of recommendations could follow later, in the more localised contexts of different forensic laboratories and police jurisdictions.

Integration

The two-part nature of this program of research was such that the results could be integrated at two stages: at the end of Part 1 (document analyses) and at the end Part 2

[3] Particularly when numerical data result, content analyses are often post-positivist in approach. In the content analyses undertaken to explore the readability of expert reports, overall a qualitative-dominant approach was used, although it included both qualitative and quantitative elements. Reports were assessed for their content and sequence, language, and format using qualitative features. Quantitative features were included as heuristic indicators of reading difficulty (see e.g., Howes et al., 2014).

(interview studies; see Creswell & Plano Clark, 2011). As noted earlier, integration at the levels of complementary knowledge and evidence or partial explanation are consistent with dialectical pluralism, as both parts of the research offer partial knowledge that contributes to an understanding of the issue. The findings from qualitative and quantitative analyses were integrated within each document study (epistemological integration – as qualitative and quantitative data provided complementary findings). They were also integrated after the completion of three document studies (some technical integration – as the units of analysis were the same; but primarily explanatory integration – as the findings contributed to a convincing and generalizable argument). I found from document analyses that the expert reports were often written in such a way that would be difficult for non-scientists to understand, although they were suitable for other experts. The overall findings were were evaluated in light of standards for reporting (Howes et al., 2014) and then used to make recommendations for the forensic scientists who write expert reports (Howes, 2015b).

The findings from analysis of the interviews with practitioners confirmed that many report-users perceived that the reports were not written at a level suited to their needs and supported the recommendations made after the document analyses (Howes, 2015c). The interview findings led to additional, broader recommendations about the communication of forensic science, which were not restricted to written reports. For example, they included the need for modifications to courses about forensic science for police detectives, and changes to communication protocols to ensure adequate opportunities for discussion between forensic scientists and police investigators (Howes, 2015c).

Depending upon which aspects of the recommendations are adopted in practice, and which organisations are willing to engage in modification and evaluation of their practices, follow-up testing of recommendations may be designed to test modified reporting styles aimed to better meet the needs of report-writers and/or users, or instructional approaches in detective training, or communication protocols between laboratories and policing organisations.

Writing and Reporting

Although dialectical pluralism is suited to a dualist approach to rhetoric, other considerations are the intended (multi-disciplinary) audience, the researcher's discipline (Creswell & Plano Clark, 2011), and the requirements of particular journals. I approached the writing of research in a mode consistent with constructivist notions of writing through the research process, updating, modifying, and refining as I proceeded. In the initial drafts, I approached the writing from a background in psychology, and used the style of the *Publication Manual of the American Psychological Association* (APA, 2010; referred to hereafter as the *APA Style Guide*) as the basis for my style choice, with three caveats.

First, the *APA Style Guide* is based on scientific reporting styles, and represents a post-positivist approach to reporting of research (Sandelowski, 2003). Therefore, although comprehensive, the *APA Style Guide* is more informative on the presentation of quantitative, than of qualitative or mixed-methods research. Consequently, I needed to draw from respected qualitative methodologists to achieve appropriate rigor and quality in a dualist approach to reporting in mixed voice. My reporting of qualitative studies, and integration of results of different studies and phases, may be viewed as departures from the style of the *APA Style Guide*. Although the reporting of qualitative studies can include creative expression such as the use of poetry, for example (Greene, 2008; Leech, 2012), my reporting did not, and may be viewed as a moderate approach to mixed voice, influenced as it was by the *APA Style Guide*, consideration of the intended readership, and the requirements of the respective journals.

Second, despite the reported tendency for researchers from a post-positivist standpoint to use passive sentence constructions and the third person (Roland, 2009), the *APA Style Guide* recommends use of the active voice; use of the first person "I" to make clear researcher decisions (when describing steps in the process); clarity of expression, and avoidance of jargon (see APA, 2010, pp. 65-70).[4] Finally, I agree with the principle expressed by Plaxco (2010), that clarity and ease for the reader is the paramount consideration. Thus, departures from the guidelines are justified, to the extent that clarity is enhanced for the reader.

Writing about Methodology in a Research Report

Alise and Teddlie (2010) suggested that researchers, and in particular researchers in applied disciplines, should consider explicitly stating their philosophical standpoint and how it affected the conduct of their research. Whilst practical aspects of methodology, such as sampling, or data analysis tend to be allocated space under the method section of a report, philosophical considerations do not. The structure of the example presented below was based on a sample purpose statement introducing a sequential exploratory mixed-methods study (Creswell & Plano Clark, 2011, p. 156), with the addition of information about philosophical stance.

> The purpose of this research project was twofold: (1) to understand the communication that occurs between forensic scientists and non-scientists in the criminal justice system, including police detectives, lawyers, and judges; and (2) to recommend modifications to current practice to improve the effectiveness of the communication. The project was conducted under a meta-paradigm of dialectical pluralism (Johnson, 2011). Dialectical pluralism values dialogue

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[4] It had been my intention to write using the first person, and in fact, I recommended that forensic scientists should do so to make clear to readers of their reports where their expert opinion began. I wrote the paper reporting the first of the document analyses in the first person. Realising that the vast majority of the submissions to the journal would be written using the third person, I became self-conscious and changed it to the third person prior to publication. This was a powerful and personal illustration to me of the power of disciplinary norms, many of which, having studied psychology, I shared with forensic scientists.

between different perspectives (primarily, in this case, constructivism and post-positivism) in order to address research questions most completely. The program of study employed an over-arching mixed-method, sequential design (Creswell & Plano Clark, 2011) with content analyses of expert reports and interviews of practitioners' perceptions of the effectiveness of communication about forensic science. The mixed methods approach was essential to gaining an understanding of current practices in the communication about forensic science and the perspectives of scientists, police, lawyers, and judges about its effectiveness. Following studies of the readability of expert reports and interviews with practitioners about their experiences of the communication about forensic science in their roles in the criminal justice system, a number of recommendations were made with a view to improving the effectiveness of such communication. It remains to test the recommendations in follow-up studies, in consultation with practitioners and their organisations.

Conclusion

In this paper, I presented a documented example of one approach to working through the process involved in developing the methodology for a mixed research project. In that respect, this paper is located in the domain of guidelines for practice. Dialectical pluralism reflects my developing meta-philosophical stance. The explicit valuing of different perspectives was consistent with my concerns at the outset of this interdisciplinary project, not only to value the different practitioners' perspectives, but to value different methodological approaches to addressing it. The use of a qualitative-dominant mixed-methods program of research was appropriate to engage in the viewpoints of various groups of practitioners, and in thinking about communication theory that would form a relevant foundation for the work. Ongoing reflexivity throughout the research has allowed me to question and re-affirm my alignment with this approach throughout the project to date. I recognise that further development of my position may arise not only as I turn the gaze on my own research process, but also in response to ongoing debates and controversies in mixed research (Creswell, 2011), and looking closely at the positions adopted by other researchers. This documented example was an attempt to respond to the call from methodologists for researchers to explicate their methodologies with philosophical clarity. The messiness of the thinking process is hard to capture in a linear sequence. However, I hope that this contribution to the discussion of mixed-methods practice may be helpful to other researchers who are navigating similar issues in the course of mixed-methods research, particularly in applied and interdisciplinary contexts.

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Part 2

Studies of the Readability of Expert Reports

4

Forensic Scientists' Conclusions:
How Readable Are They for Non-Scientist Report-Users?

This chapter has been published as follows:

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Abstract

Scientists have an ethical responsibility to assist non-scientists to understand their findings and expert opinions before they are used as decision-aids within the criminal justice system. The communication of scientific expert opinion to non-scientist audiences (e.g., police, lawyers, and judges) through expert reports is an important but under-researched issue. Readability statistics were used to assess 111 conclusions from a proficiency test in forensic glass analysis. The conclusions were written using an average of 23 words per sentence, and approximately half of the conclusions were expressed using the active voice. At an average Flesch-Kincaid Grade level of university undergraduate (Grade 13), and Flesch Reading Ease score of *difficult* (42), the conclusions were written at a level suitable for people with some tertiary education in science, suggesting that the intended non-scientist readers would find them difficult to read. To further analyse the readability of conclusions, descriptive features of text were used: text structure; sentence structure; vocabulary; elaboration; and coherence and unity. Descriptive analysis supported the finding that texts were written at a level difficult for non-scientists to read. Specific aspects of conclusions that may pose difficulties for non-scientists were located. Suggestions are included to assist scientists to write conclusions with increased readability for non-scientist readers, while retaining scientific integrity. In the next stage of research, the readability of expert reports in their entirety is to be explored.

Forensic Scientists' Conclusions:

How Readable Are They for Non-Scientist Report-Users?

The primary ethical responsibility of forensic scientists is to communicate their findings and expert opinions clearly and correctly to audiences that typically do not have any scientific training (Willis, 2009). Non-scientist audiences of forensic scientists' findings and expert opinions (or scientists' interpretations of, and inferences from, their scientific findings) include police investigators, lawyers, judges, and jurors. To use scientific findings and expert opinions as decision-aids within the criminal justice system, non-scientist audiences need to understand what forensic scientists present to them and its significance. According to Willis (2009), forensic scientists' responsibility extends to ensuring that non-scientist audiences understand the strengths, weaknesses, and uncertainty associated with the findings and expert opinions. Miscommunication or misinterpretation of these findings and opinions has the potential to lead to flawed decisions and has been implicated in past wrongful convictions (Garrett & Neufeld, 2009).

Past research has aimed to address the issue of communicating scientific expert opinion to non-scientists through exploring the impact of forensic scientific testimony on fact-finders' verdicts. Issues in communication included conveying the strength of evidence (Koehler, 2011; McQuiston-Surrett & Saks, 2009; Smith, Bull, & Holliday, 2011); juror characteristics; and the channel of communication (e.g., traditional testimony versus a multimedia presentation; Goodman-Delahunty & Hewson, 2010). These studies highlighted the complexity of communicating scientific expert opinion, but they focused on courtroom communication. In fact, relatively few cases go to trial; of these fewer are jury trials (Blumenthal, 2002) and fewer still contain expert testimony.

Scientific advances in recent decades (Smith et al., 2009) have meant that police investigators, lawyers, and judges may increasingly encounter forensic scientific evidence in their roles within the criminal justice system. Forensic scientific findings may be used to direct police investigations (Esseiva et al., Robinson & Tilley, 2009), or to make prosecutorial decisions (Peterson, Hickman, Strom, & Johnson, 2013). However, exposure to science does not equate to comprehension of it (de Keijser & Elffers, 2012). Lawyers reported difficulties in understanding scientific terminology and in applying a general understanding of a scientific discipline to specific cases (Cashman & Henning, 2012). Face to face communication was limited: Meetings between forensic scientists and police investigators were relatively common for homicide, but not for rape cases (Kelty, Julian, & Ross, 2013). Pre-trial conferences between forensic scientists and lawyers tended to be both brief (Kelty et al., 2013), and under-used (Ledward, 2004). This issue was compounded for defence lawyers due to limited time and budgetary constraints (Cashman & Henning, 2012).

Due to these types of issues, the basis for communication between scientists and police investigators, lawyers, and judges is usually a written report (Rothwell, 2010). Reports include interim reports issued to police investigators once initial testing has been conducted, expert reports issued to police investigators at the conclusion of testing, and expert certificates or statements prepared specifically for the courts[1]. The reports may differ in format according to the circumstances of the case, the preferences of the scientist, the reporting guidelines of the laboratory (Rothwell, 2010), and the specifications of the courts (e.g., Keane, 2011). For non-scientist report-users, unless an aspect of forensic testing is in dispute, the level of detail provided in expert reports may be beyond what is of interest. According to Rothwell, at least some readers may read only the conclusion of the report (Rothwell, 2010).

[1] In Australian jurisdictions the reports issued to police investigators usually differ in style and content from the statements issued to the courts. However, at times, reports issued to police investigators are used in the courts.

Given the importance of conclusions in communicating scientific expert opinion to non-scientists, conclusions – and written conclusions in particular – are the focus of the present study. This study is the first in a larger programme of ongoing research into the communication of scientific expert opinion. In the larger project, expert reports are considered in their entirety. In addition, the larger project explores relevant perspectives, namely those of forensic scientists as report-writers and those of police investigators, lawyers, and judges as report-users.

Part 1 – Readability and Readability Formulas

Readability refers to the ease with which something can be read and understood due to the style of writing (Klare, 1963) and is a prerequisite to comprehensibility (Badarudeen & Sabharwal, 2010). One aspect of writing that hinders readability, and for which scientists have been criticised, is a preference for the use of the passive rather than the active voice (Roland, 2009). A sentence such as, "Scientists wrote reports," in the active voice becomes "Reports were written (by scientists)" in the passive voice. The passive voice permits the omission of the agent (in this case, "scientists"). Consequently, the passive voice leads to ambiguity and confusion whereas the active voice shows honesty as the writer takes more personal responsibility (Roland, 2009).

Strong predictors of reading difficulty include sentence length and word frequency (Crossley, Duffy, McCarthy, & McNamara, 2007). Because of this, readability scores based on quantifiable characteristics of texts perform relatively well (Benjamin, 2012). Readability formulas include the Flesch-Kincaid, the Gunning Fog, and the SMOG indexes. They use features of text, such as the number of words per sentence and the number of syllables per word, to calculate a score, often given as a grade level[2]. The grade level calculated is intended to reflect the minimum level of educational attainment

[2] For example, the formula for the Flesch-Kincaid Grade Level is given by the formula, FK = 0.39 (total words/total sentences) + 11.8 (total syllables/total words) − 15.59 (Kincaid, Fishburne, Rogers, & Chissom, 1975).

necessary, based on the US education system, to read and comprehend the text. Although the scores are based on American schooling, it is assumed that they reflect Australian levels well enough to provide a useful heuristic (Laidlaw, Spennermann, & Allan, 2007).

As an alternative to a grade level, Flesch Reading Ease (FRE)[3] is a score (from 0-100) where the lower the score, the more difficult the text. Flesch described a score of 0 as "practically unreadable" and a score of 100 as "easy for any literate person" (Flesch, 1948, p. 229). More generally, a Flesch Reading Ease score of 0 to 30 is considered *very difficult* and a score of 60 to 70 is considered *standard* (Flesch, 1948).

Researchers have used readability formulas to test the readability levels of various documents written by specialists for non-specialists including patient education materials (D'Alessandro, Kingsley, & Johnson-West, 2001; Estrada, Hyrniewicz, Higgs, Collins, & Byrd, 2000), consent forms for participation in medical research (Paasche-Orlow, Taylor, & Brancati, 2003), the academic integrity policies of Australian universities (Green & van Kessel, 2011), and bushfire risk management plans (Laidlaw et al., 2007).

Whilst online readability calculators are freely available (see e.g., Beaglehole & Yates, 2010), the Flesch-Kincaid Grade Level and Flesch Reading Ease scores in particular are widely used, probably because of their accessibility within standard computer software (Benjamin, 2012). The readability statistics provided in Microsoft Word 2010 (for the selected part of the document) include the numbers of words and sentences, and the average numbers of words per sentence, and characters per word. Scores provided, which may be particularly helpful for assessing scientific conclusions, are the percentage of sentences using the passive voice, the Flesch-Kincaid Grade Level, and the Flesch Reading Ease scores. We chose to use the readability statistics produced by Microsoft Word due to their applicability beyond the research setting. In practice, scientists may use these

[3] The Flesch Reading Ease score is given by the formula,
$\text{FRE} = 206.835 - 1.015\,(\text{total words}/\text{total sentences}) - 84.6\,(\text{total syllables}/\text{total words})$. Note that the number of decimal places provided in the formulas follows the originals.

statistics quickly and easily to obtain a simple indication of the readability of all or part of their expert reports.

Audience and Reading Ease

The audience for expert reports includes police detectives, lawyers, and judges. (Jurors may hear expert reports read aloud if they contain uncontested evidence and the scientist is not called as an expert witness; Rothwell, 2010). In Australia, science is not a compulsory school subject beyond Grade 10 (for students aged 15-16 years), and is not a prerequisite or co-requisite subject for law or justice studies at university. This means that police investigators, lawyers, and judges may not have studied science subjects in senior high school (for students aged 16-18 years) and are unlikely to have studied science at a university level. Non-scientist readers of expert reports cannot be expected to be specialists in science.

It is reasonable to suggest that the conclusions of expert reports written at or below a Grade 10 level may be read with ease by police, lawyers, and judges. However, a target of a Grade 8 level (or a range from Grade Levels 7-9) may be preferable for two reasons. First, the reports are written by forensic scientists in their areas of expertise, not in areas of reader specialty. Second, reading ability as given by a grade level is often lower than the level of schooling completed (Fuller, Horlen, Cisneros, & Merz, 2007; Ley & Florio, 1996). Given the issues identified by past research in communicating scientific expert opinion to fact-finders, it was hypothesised that the conclusions of expert reports would be written at levels that would be difficult for non-scientists to read.

Method

Sample. The sample consisted of a set of 111 conclusions written as part of an international proficiency test for forensic scientists who conduct glass analysis. *Collaborative Testing Services, Incorporated* (CTS) provides online summary reports of the results of the tests for the purpose of assisting participants in "maintaining or enhancing the quality of their results" (Collaborative Testing Services [CTS], 2011, p. 3). Our purpose in using the Summary Reports accords with this aim[4]. CTS (2011) reported that the test had been sent to 148 potential participants, of whom 111 completed and returned the test (78% response rate).

To maximise the value of proficiency tests, accreditation bodies request that test participants subject the test items to their routine analytical methods and reporting procedures. In Australia, for laboratories to maintain accreditation, the National Association of Testing Authorities (NATA) requires that their scientists participate in proficiency tests in the scientific disciplines in which they undertake casework (NATA, 2012). However, not all participants in CTS tests are from accredited organisations; therefore, some responses examined in our research may not be representative of real case reports. Although all test responses were written in English, it should be noted that some test participants may not typically write their casework conclusions in English, as the test is offered internationally. Test participation is anonymous; therefore, specific data were not available on participating jurisdictions.

Test participants had received 3 glass fragments (1 known and 2 unknown) and a case context[5]. The test asked participants 3 questions. First, participants were asked to select *yes*, *no*, or *inconclusive* in response to the question of whether the "glass particles in Items 2 and/or Item 3 could have originated from the broken glassware as represented by Item 1?" (CTS, 2011, p. 31). Second, they were asked to "indicate the procedures used to

[4] The information obtained from the *Glass Analysis Test No. 11-548 Summary Report* was used with the permission of CTS.

[5] The case context provided was as follows:
"Police are investigating a home invasion where a woman was brutally attacked and found unconscious in the kitchen. Investigators have recovered fragments of glassware found on the kitchen floor. Witnesses claim to have seen her ex-boyfriend driving around the neighbourhood. The suspect was apprehended at a local bar near the woman's home. Police have recovered glass particles from the suspect's wool sweater and from the driver's seat of his car. Investigators have submitted the recovered glass particles along with a sample of broken glassware recovered from the kitchen for analysis." (CTS, 2011, p. 31)

examine the submitted items" (CTS, 2011, p. 32). Third, participants were asked "What would be the wording of the Conclusions in your report?" (CTS, 2011, p. 33) and a space of 8 lines was provided. Finally, a section containing 4 lines was left for additional comments.

Measures. Microsoft Word 2010 was used to obtain scores for *readability* (Flesch-Kincaid Grade Level and Flesch Reading Ease score), *length* (number of sentences in the conclusion and average number of words per sentence), and *sentence structure* (percentage of sentences in the passive voice).

Procedure. Conclusions were obtained from the *Glass Analysis Test No. 11-548 Summary Report* (CTS, 2011) available in the Forensic Testing Program section of the CTS website (http://www.ctsforensics.com/reports/main.aspx). The conclusions were copied from the PDF Summary Report into a Microsoft Word 2010 document. Each conclusion was checked to ensure that it had been transferred as a single paragraph. Spelling and grammatical errors (where present) were retained; however, where "[sic]" had been inserted after spelling errors, it was removed prior to obtaining readability statistics. (To obtain the readability statistics in Microsoft Word 2010, the user clicks on the *Review* tab, selects *Options* within the *Spelling and Grammar* pane, and checks *show readability statistics*.)

Results

Table 1 shows the means, standard deviations, and ranges of the readability statistics obtained. Overall, 20% of sentences in conclusions were written using the passive voice. In 49% (n = 54) of conclusions the passive voice was not used, while in 51% (n = 57) of conclusions the passive voice was used in at least one sentence. In conclusions where the passive voice was used, usage ranged from 12-100% of sentences (M = 39%). In two conclusions, the passive voice was used exclusively.

Table 1

Ranges, Means, and Standard Deviations for Quantitative Features of Conclusions

Readability Statistics[a]	Range	Mean	Standard Deviation
Words in total	14-292	91.2	50.7
Sentences	1-13	4.1	2.3
Average words per sentence	2-53.5	23.8	8.6
Average characters per word	3.7-6.1	4.9	0.5
Sentences in passive voice (%)	0-100	20.0	24.0
Flesch Reading Level	0-78.8	42.4	16.3
Flesch-Kincaid Grade Level	5.4-25.2	13.1	3.9

Note. *N* = 111 conclusions from *Glass Analysis Test No. 11-548 Summary Report* (CTS, 2011).
[a]Readability statistics obtained from Microsoft Word 2010.

As can be seen in Table 2, with a mean Flesch-Kincaid Grade level of 13 and Flesch Reading Ease of 42, most conclusions were classified as *difficult* or *very difficult*.

Table 2

Conclusions by Flesch Reading Ease and Flesch-Kincaid Grade Levels

Flesch Reading Ease Score[a]	Description of Style[a]	Estimated Flesch-Kincaid Grade Level[b]	Range of Grade Levels Obtained in Conclusions	Conclusions % (n)
0 to 30	*Very difficult*	College graduate	13.4-25.2	23 (25)
30 to 50	*Difficult*	13-16	8.7-18.4	49 (54)
50 to 60	*Fairly difficult*	10-12	8.1-13.9	14 (15)
60 to 70	*Standard*	8-9	6.3-12.1	10 (11)
70 to 80	*Fairly easy*	7	5.4-9.0	5 (6)
80 to 90	*Easy*	6	NA	0 (0)
90 to 100	*Very easy*	5	NA	0 (0)

[a](Flesch, 1948, p. 230); [b](Flesch, 1949, p. 149).

Discussion

The hypothesis that scientific conclusions would be difficult to read for non-scientists was supported by readability statistics. Given that the conclusions examined in this study were each restricted to a single paragraph, the length of the text was not viewed as an impediment to readability. However, a number of conclusions contained long sentences, with the average sentence length over 23 words. This sentence length was associated with *fairly difficult* texts (Flesch, 1948). A blend of long and short sentences is natural and may enhance readability (American Psychological Association [APA], 2010).

Although scientists have been criticised for their overuse of the passive voice (Roland, 2009), only half of the conclusions used the passive voice, and of these a small proportion of scientists made extensive use of the passive voice. Because the proficiency tests are anonymous and international, it is not known whether the use of the passive voice is a preference of some scientists or associated with the reporting guidelines of some laboratories.

Approximately half of the conclusions were written at a level which would be considered *difficult* and almost one-quarter were *very difficult*, according to Flesch's Reading Ease scale (Flesch, 1948). About one-eighth of conclusions were written at a *fairly difficult* level, another one-eighth were *standard* or *fairly easy* but none of the conclusions were written at a level corresponding with *easy* or *very easy.* Whilst the perception of difficulty depends upon the individual reader, the conclusions were written at an average grade level of 13, suggesting that some university education would be necessary to read them with ease. It is reasonable to suggest that the conclusions would be difficult to read even for people with a university education, if that education were not in science.

Limitations. Despite their heuristic value, readability formulas have been criticised because it is possible for nonsensical passages of short words and sentences to obtain high scores on reading ease and low grade-level scores (Benjamin, 2012). One of the simplest ways to decrease the grade level or to increase the reading ease score is to break the paragraph into more sentences (Beaglehole & Yates, 2010). This is a solution to the readability issue that is supported by the results. However, using readability statistics in isolation, as a tool to inform writing, is not recommended because this may result in artificial texts which do not facilitate comprehension (Klare, 1981). To write readable texts, it is more important to follow principles of good writing, using readability statistics only as a heuristic guide. To identify the aspects of the conclusions that may be simplified to enhance readability, qualitative aspects of their readability were next explored.

Part 2 – Qualitative Examination of Readability

Certain issues with readability, which cannot be detected automatically by computer programs, may be detected by people (Chall, Bissex, Conrad, & Harris-Sharples, 1996). The considered use of figures, tables, photographs, white space, and the careful selection of font and font size (Badarudeen & Sabharwal, 2010) can enhance readability. Using the sample of conclusions written as part of a proficiency test for forensic glass analysts, it was not possible to assess these features. However, it was possible to qualitatively assess the sample of conclusions for other helpful textual features.

To assist teachers to determine the appropriateness of written material for their students, Graves and Graves (2003) identified six factors inherent in texts that affected readability and could be assessed qualitatively. The six factors (length, sentence structure, text structure, vocabulary, elaboration, and coherence and unity) have appeal beyond the educational setting as they can be used to assess a wide variety of written materials. Although long passages may present an obstacle to readers (Graves & Graves, 2003), the potential issue of length of reports for non-scientists has been addressed by selecting the conclusions of reports – the part of reports most likely to be read by non-scientist report-users (Rothwell, 2010). Because this aspect was considered in Part 1, it is not re-examined in detail here.

A further four factors involved both the reader and the text: familiarity of content and background knowledge required; audience appropriateness; quality and verve of the writing; and interestingness (Graves & Graves, 2003). Two of these factors, background knowledge required and audience appropriateness, were considered in Part 1, and are considered within the discussion of factors inherent in text. The factors of quality and verve of the writing and interestingness may be more readily applicable to fiction writing. Indeed, Graves and Graves acknowledged that in certain instances, straightforward prose was appropriate and desirable. Therefore, quality and verve of the writing and interestingness are not considered in depth.

Text Structure

The organisation of a text can facilitate or hinder comprehension (Graves & Graves, 2003). Clearly organised text, with a degree of predictability of structure, facilitated readability (Chambliss & Calfee, 1998). It cannot be assumed that non-scientist report-readers would be familiar with the appropriate structure of conclusions as presented by scientists in expert reports.

Sentence Structure

The use of long and complex sentence structures makes comprehension more difficult; but keeping sentences artificially short can be problematic (Graves & Graves, 2003). Even readers with low reading ability preferred – and better comprehended – more natural sounding text, even if it was theoretically more complex (Green & Olsen, 1998). Therefore, varied sentence length is preferable (APA, 2010). As an additional index of readability, Flesch developed a Human Interest score, based on the number of personal words per hundred words and personal sentences per hundred sentences (Colman, 2001; Flesch, 1948). Although *interestingness* may be more applicable to other text-types, the use of the first person in conclusions can be considered.

Vocabulary

It is essential that vocabulary appropriate to the discussion be used; simpler words are not always better (Graves & Graves, 2003). Using words with precise meanings is appropriate for clarity of written expression; precise terms are particularly appropriate for describing empirical observations. However, the unnecessary use of jargon or technical vocabulary hinders communication (APA, 2010).

Elaboration

Providing illustrative examples of material (or in-text definitions) enhanced readers' recall of information, but needed to be balanced with length (Graves & Graves, 2003). Inferences made explicit in text aided reader comprehension (Kintsch & van Dijk, 1978). McNamara and Kintsch (1996) found that novices reading about an unfamiliar topic needed inferences to be made explicit. When the inferences were not made, novice readers often did not make the inferences necessary for text comprehension. In contrast, experts benefited from making inferences themselves (to promote deeper-level processing).

Coherence and Unity

It is important that there be a clear purpose of the text, and links between parts of the text (Graves & Graves, 2003). Britton and Gülgöz (1991) developed three principles for revising texts based upon Kintch's (1978) model of text comprehension. First, each sentence should be linked to the previous sentence through the use of overlapping propositions and arguments; and the same terms should be used consistently to refer to the same concepts. Second, sentences should be arranged such that old information preceded new information. Third, inferences should be made explicit. When text was rewritten according to these principles, participants performed better on free recall and multiple choice tests than did their counterparts reading the original text, even though the Flesch-Kincaid Grade level remained unchanged (Britton & Gülgöz, 1991).

In Part 1 of this paper, a need was identified for increased readability of conclusions for non-scientist readers. In Part 2, qualitative features of texts were used to assess the readability of expert conclusions for non-scientist readers. The aim was to evaluate whether and how increased readability could be achieved through changes to qualitative features of the texts. The purpose was not to suggest changes to the content of conclusions, but to identify possible ways to increase the clarity of conclusions, for non-scientist readers, through changes to the structure and expression of conclusions.

Method

Sample. The main sample of conclusions was described in Part 1. In addition, after coding the content of the Conclusions from the Results Summary Report (CTS, 2011), the Additional Comments section was read. Thirty-four participants had used the additional comments section. In this section, participants had supplemented their conclusion (as opposed to presenting a comment about the test to its authors). This was evidenced by the presence in this section of information categories that had been coded in the conclusions (e.g., inference of results, limitations, attachment of a scale or glossary). To best reflect the range of information presented by scientists, it was decided to code the conclusion-related information contained within the additional comments section along with that of the conclusions.

Assessment of qualitative aspects of readability. To assess *text structure*, content features of text were coded until all content was coded. The sequence of the four main content features of conclusions (identified in the majority of conclusions) was then examined.

The *sentence structure* of the four main content features of conclusions was examined to determine whether compound or complex sentences were used. This was evident when sentences contained two independent clauses, each expressing a complete thought, separated by a coordinating conjunction such as “and” or a subordinating conjunction such as “because”, respectively. Conclusions were examined for the presence of at least one sentence written in the first person (as evidenced by the use of *I*, *we*, *my* or *our*).

To assess *vocabulary*, the specific words and phrases used to express each of the main content features were collated. Scientific terminology that would be unfamiliar to non-scientist readers was identified.

To assess *elaboration*, several content features were examined: descriptions of examined glass items; acronyms or abbreviations; inferences (for positive findings, negative findings, and alternative explanation for positive findings); and explicit statement of the scientist’s assumptions or information used to make an inference (the basis for similarity or difference of glass items; the limitations of techniques used; the basis for the opinion; the use of a scale to convey evidentiary significance; the provision of the scale; the rarity of findings).

Coherence and unity was assessed in three ways. The presence or absence of a statement of the purpose or the context of the comparison was recorded. Next, the use of words or phrases to make links between the key content features identified was noted. Finally, because the terms referring to items were used multiple times within conclusions, each conclusion was checked for consistent use of the terms. The types of terms used to refer to items in each conclusion were recorded (1 = item numbers only; 2 = scientific terms only; 3 = descriptive terms only; 4 = combination of item numbers and scientific terms; 5 = combination of item numbers and descriptive terms; 6 = combination of item numbers, scientific, and descriptive terms). The use of parentheses in terms referring to items was coded (1 = neither; 2 = numerical term; 3 = scientific/descriptive term).

Results and Discussion

Results are presented below for each of the qualitative features of conclusions assessed. Percentages are provided (with the number of conclusions in parentheses); however, when a result applied to a small proportion of conclusions, the percentage and number of conclusions did not differ and in these cases whole numbers are given.

Text structure. Twenty-five content features were identified in the conclusions (and the additional comments section which followed them). Table 3 shows the content features and the proportion of conclusions in which they were present. As can be seen in Table 3, the four most common content features were positive findings from a comparison, the associated inference, negative findings from a comparison, and the associated inference.

The most common format for reporting these four content features in conclusions was a parallel structure. In this style of conclusion, almost always, the positive finding and inference were reported followed by the negative finding and inference. This format was used in 55% (*n* = 61) of conclusions. In contrast, 45% (*n* = 50) of conclusions reported only one, two, or three of the four most common features of text, in various combinations, and thus often did not present parallel text structures.

Table 3

Proportion of Conclusions Containing Each Content-Type

	Code	%	(*n*)	Example of Content[a]
1	Item description (as context sentence)	14	(16)	Item 1 was the known glass fragment recovered from the victim's kitchen.
2	Context or purpose	20	(22)	… were examined; were examined to determine whether they were like …
3	Techniques / instruments used for comparison	17	(19)	…the Glass Refractive Index Measurement system (GRIM3) and a density comparison technique.
4	Link findings and analytic techniques	5	(6)	Analysis showed … / Based on our examination …
5	Positive findings from comparison	77	(85)	… could not be distinguished from… / …was consistent with…/…to be similar…
6	Basis for findings	66	(73)	… in colour, density, and refractive index.
7	Link finding and inference (positive)	57	(63)	Therefore, … / Based on these findings, …/ This means …
8	Explicit opinion	10	(11)	In my opinion…/ It is the opinion of this analyst …
9	Inference from positive findings	81	(90)	… could have originated from the same source as …
10	Alternative explanation for inference	38	(42)	However, other sources of glass are possible.
11	Support for positive proposition	17	(19)	These findings provide support for the proposition that …
12	Limitation of findings	10	(11)	Further testing (elemental analysis) is possible but not available at this laboratory.
13	Rarity of findings	2	(2)	Of the samples of broken glass collected from crime scenes and survey samples examined at our laboratory …. 2.3% are indistinguishable …
14	Negative findings from comparison	77	(85)	…could be distinguished by…/… was not consistent with …/ …are dissimilar …
15	Basis for findings	49	(54)	…in refractive index. / … in elemental composition.
16	Explicit opinion	5	(5)	In my opinion…/ It is the opinion of this analyst …

Table 3 continues overleaf

Table 3 continued

17	Link findings and inference (negative)	57	(63)	Therefore, … / Based on these findings, …/ This means …
18	Inference from negative comparison	72	(80)	… was ruled out as a possible source of …
19	Support for negative proposition	6	(7)	… support that …
20	Conclusion scale apparently used	18	(20)	Moderately strong support
21	Conclusion scale provided	11	(12)	I have chosen the above phrase from the following scale: weak support, moderate support…
22	Basis for opinion	2	(2)	These conclusions are based on the information I have received and my laboratory examination.
23	Limitations of information/items received	8	(9)	Not enough information received. The answers to the following questions and the submission of the jumper for examination would potentially allow...
24	Information about interpretation	9	(10)	The glass fragments in Item 2 were larger than I would expect to find on the surface of an item of clothing….I have made the assumption that they were recovered from a pocket.
25	Key to acronyms used	2	(2)	Key for instrument acronyms: GRIM 3 = Glass Refractive Index Measurement 3…

[a]Comments about the scientific validity of examples of content cannot be made as they appear here in isolation from the full conclusions.

Sentence structure. In 80% (*n* = 89) of conclusions, separate sentences were used to present a finding and a related inference. However, a single compound or complex sentence was used to present both a finding and an inference in 20% (*n* = 22) of conclusions.

Despite the exclusive use of the active voice in almost half of the conclusions, noted in Part 1 of this paper, the use of the first person was not particularly common, except in phrases such as “in my opinion” or “I have chosen the above phrase from the following scale." In only 14% (n = 16) of conclusions, was one sentence or more written in the first person.

Vocabulary. Terms that were routinely used by scientists in conclusions and that would be unfamiliar to non-scientists included the use of scientific terms to refer to the items (e.g., "the questioned glass"), acronyms referring to scientific apparatus (e.g., GRIM3), terms referring to unfamiliar scientific apparatus (e.g., "scanning electron microscope"), abbreviations of chemical elements, abstract terms describing the way in which glass items differed (e.g., "optical properties", "refractive index"), and long and uncommon words (e.g., "indistinguishable").

A wide range of expressions was used to express the content features. For example, 72% (n = 80) of conclusions contained an inference about the negative comparison. This inference was expressed in 43 different ways, commencing with 14 different verbal constructions (e.g., "could not have"; "did not"; "is eliminated") and followed by a broad range of expressions (e.g., "originated from"; "come from the same source as"; "as a possible source of").

Elaboration. Descriptive terms (e.g., "the glass from the kitchen") were used to refer to items in 54% (n = 60) of conclusions. In 46% (n = 51) of conclusions no such descriptive terms were used; however, 8% (n = 9) of these conclusions contained observations as descriptions of the fragments of glass received for comparison (e.g., "full thickness glass fragment") or defined them in scientific terms (e.g., "Item 1: Glass standard.").

Acronyms and abbreviations were used in 13% (n = 14) of conclusions. Of these, most used the term in full in the first instance with the abbreviation in parentheses, two provided a key to acronyms and abbreviations in the comments section, but "UV" was used in seven conclusions and "nD" was used in two conclusions without explanation. Abbreviations for chemical elements were used in one conclusion and two comments sections without explanation.

Inferences of common origin were reported in 81% (*n* = 90) of conclusions for the positive finding, and of these 5 also contained support for a proposition. A further 13% (*n* = 14) contained support for a proposition, without an explicit inference about a common origin. A total of 38% (*n* = 42) of conclusions provided an alternative explanation for the common origin. In total, 71% (*n* = 79) of conclusions contained an inference about the negative finding, three others supported a negative proposition.

In reporting inferences, some information upon which they were based was often included. In 66% (*n* = 73) of conclusions, when a positive finding was reported, the properties that were similar in the compared glass fragments were explicitly stated (e.g., "in refractive index"). In 49% (*n* = 54) conclusions, when a negative comparison was reported, the properties that differed were explicitly stated. In 10% (*n* = 11) of conclusions, an inference was preceded by an explicit statement that an opinion was to be provided. In 13% (*n* = 14) of conclusions, scientists stated that the inference/s were based upon the results; two conclusions included a list of additional information upon which the opinion provided was based.

In 10% (*n* = 11) of conclusions, the limitations of findings were stated (five in the conclusion and six in comments). Limitations reported included temporary instrument failure, and the lack of availability of more conclusive testing within the particular laboratory. In 18% (*n* = 20) of conclusions, it appeared that a conclusion scale was used in expressing a level of support for a proposition or the significance of the evidence. In 11% (*n* = 12) of conclusions, scales were provided. Of these, five were provided in text, three in the comments section, and four as a separate attachment (noted by CTS in the comments section).[1] Of conclusions in which scales were provided, one explained the basis for the scale (as logarithmic).

In the additional comments section, 9% (*n* = 10) of participants provided additional information about interpretation (e.g., statistical treatment, research information, apparatus used, or chemical elements considered). Eight percent (*n* = 9) of participants provided information about what they considered to be the limitations of the items and/or information (e.g., "in the absence of information…the proposition was addressed at source level rather than activity"; "Item 1 was too small…may not have been representative of the standard"). Two participants provided a key to acronyms used in the conclusion. No conclusions had contained information about the rarity of the findings; however, two participants included information about match frequency data for their laboratories in the additional comments section.

Coherence and unity. In 25% (*n* = 28) of conclusions, a statement providing the context or purpose for the conclusion was provided. Contextual statements included referring to a "comparative examination", an "examination", or a "comparison" of samples of glass fragments. Two conclusions made explicit the purpose of the comparison, "to determine if they are like the fragment of known glass…". In 14% (*n* = 16) of conclusions, a sentence describing items served as a contextual statement.

Five percent (*n* = 6) of conclusions contained links from the analytical techniques used to the results obtained, by introducing results with a reference to the analysis (e.g., "Analysis showed…"). However, the focus of this analysis was on links between the four

[1] The 2011 Summary Report was used in preference to the 2012 report because the 2012 test explicitly stated that participants should not include conclusion scales and other appendixes with the data sheet as they would not be reprinted in the Summary Report. In the 2011 report, (although attached scales were not reprinted), CTS included a note in the comments section that a scale had been included. Although the policy not to reproduce attachments was not explicitly stated on the 2011 data sheet, some participants may have been aware of the policy. This may have resulted in the inclusion of fewer conclusions scales and acronym keys than would be typical of expert reports in routine casework.

main content features. Phrases that introduced inferences with a link to results (e.g., “Based on these results…”, “Therefore…”) were present in 57% (*n* = 63) of conclusions, whereas 43% (*n* = 48) of conclusions did not contain any links between findings and inferences.

The majority of space in many conclusions, and in conclusions in total, was taken up by the terms used to refer to the items compared. Several different terms were used to describe the same items, often within the one conclusion. These terms included item numbers (e.g., “Item 2”), generic scientific terms (e.g., “the unknown glass”), descriptive terms (e.g. “glass fragments recovered from the suspect’s sweater”), and combinations thereof (see Table 4). A strong preference (69%; *n* = 77) for use of terms in combination was observed. In cases where terms were used in combination, they were used both in apposition (strings of nouns; e.g., “the fragments of questioned glass Item 2 [recovered from suspects sweater]”), or were used interchangeably within the paragraph. Of the conclusions in which item numbers were used in conjunction with descriptive and/or scientific terms, 68% (*n* = 52) used parentheses as part of the terms. Of these, 36% (*n* = 40) enclosed the item number and 7% (*n* = 8) enclosed the term in parentheses.

In 31.5% (*n* = 35) of conclusions all three types of terms (descriptive, scientific, and numerical) were used to refer to items. The next most common way to refer to items was by using the item number in isolation; this occurred in 27% (*n* = 30) of conclusions. An item number with a descriptive term and an item number with a scientific term were each used in 19% (*n* = 21) of conclusions. Item descriptions alone were used in 3.5% (*n* = 4) of conclusions.

Table 4

Examples of Terms Used to Refer to the Glass Samples Compared

Reference Terms	Examples for Item 1	Examples for Item 2[b]	% (*n*)
Item numbers only	Item 1; Exhibit 1; item 1; item 001; item 001-1; item #1; # 1; "item 1"; "1"	Item 2; Exhibit 2; item 2; item 002; item 001-2; item #2; #2; "item 2"; "2"	27.0 (30)
Scientific terms only	Glass standard; standard glass; the known glass fragment; control glass; the known glass from the broken glassware	The unknown glass; the questioned glass; questioned sample; questioned glass particles; questioned glass fragments	0.0 (0)
Descriptive terms only	The broken glass recovered from the kitchen; the glass from the kitchen; the colorless glass from the broken glassware in the kitchen; the sample of glass from the broken glassware from the victim's kitchen	Glass fragments recovered from the wool sweater; the two pieces of glass recovered from the suspect's wool sweater; the recovered fragments from the suspect's wool sweater	3.5 (4)
Item numbers and scientific terms[a]	The known glass in Exhibit 1; the known glass (Item 1); the control sample (item 1); the known glass source from Item 1	The unknown glass (Item 2); the questioned glass (item 2)	19.0 (21)
Item numbers and descriptive terms[a]	The piece of glass from the broken glassware from the kitchen (item 1); the glassware from the kitchen (item 1); the broken glassware from the kitchen as represented by Item 1	The two pieces of glass recovered from the suspect's wool sweater (item 2); the glass from the suspect's sweater (Item 2)	19.0 (21)
Item numbers, scientific, and descriptive terms[a]	The known glass sample recovered from the kitchen Item 1; the known sample of broken glassware recovered from the kitchen (item 001)	The questioned glass fragments recovered from the suspect's sweater (Item 2); the two questioned glass fragments recovered from the suspect's wool sweater (item 002)	31.5 (35)
		Total	100 (111)

[a]For terms used in combination, in addition to the examples of apposition (noun strings) presented here, was use of terms as interchangeable.
[b]The wording for Item 3 (not included on the table) was similar to wording for Item 2, with number and description change.

General Discussion

Qualitative analysis of conclusions supported the results of readability statistics, which had indicated that conclusions would be difficult for non-scientists to read. Specifically, many of the features of texts that could be expected to enhance readability of the conclusions for non-scientist report-users were observed in relatively low proportions of responses. For example, just over half of the participants reported their results and inferences using a parallel text structure. Similarly, just over half of the conclusions contained links between the results and inferences. Just over half of the participants provided item descriptions; fewer than half provided a context for the analysis. Few participants outlined the assumptions upon which they based their conclusions.

Possible Solutions to Readability Issues in Conclusions

Examples of specific issues observed in the conclusions of the sample of proficiency tests and ways to address them are presented below. It is important to note that not all of the issues that follow would be regarded as problematic in the case reports of all jurisdictions. Some or all of the issues discussed may be adequately addressed in the existing reporting and practice guidelines for certain accreditation bodies, jurisdictions, and laboratories.

State the context or purpose. Few conclusions made explicit the purpose of the text. A simple statement such as, “Fragments of glass were compared to determine whether they were alike”, where provided, set the scene very effectively for the information that followed.

Present sufficient information. Because the conclusions were each only one paragraph, length was not initially a cause for concern. However, because some conclusions were extremely short, they provided inadequate information to report-users to ensure optimal comprehension. For example, if report-users were not made aware that the scientist's conclusion was an expert opinion (an interpretation) based on the results of the selected techniques used and the specialist education and experience, report-users may confuse expert opinion and scientific fact. Although a short conclusion of one or two sentences may be quicker for the report-user to read, this is ultimately irrelevant if it does not provide the reader with adequate information to understand the implications of scientists' findings for a case at hand.

Present key information using a clear structure. The most common approach to the conclusion was to present the results and inference for one comparison and then the next. This type of parallel construction enhanced readability, by adding predictability to structure, so the reader could make expectations about the information to follow (Chambliss et al., 1998; McNamara & Kintsch, 1996). One-fifth of conclusions that presented findings and inferences in this way, however, did so using a single compound sentence for the result and inference for each test. Consider this sentence:

> Due to differences in optical properties the questioned glass particles from Item 3 could not be associated with the known glass source from Item 1. (Flesch Reading Ease [FRE] = 46.1, *difficult*; Flesch-Kincaid Grade Level [FK] = 13.0).

In other cases, not only was a single sentence used, but also findings and inference were inverted. For example,

> The questioned glass particles from Item 3 could not be associated with the known glass source from Item 1 due to differences in optical properties. (FRE = 49.4, *difficult,* FK = 12.5).

The sentence above presented (conceptually) newer information before old information which may hinder readability as the reader sequences events (Britton & Gülgöz, 1991; Vidal-Abarca, Martínez, & Gilabert, 2000). Consider a possible alternative.

> The glass particles from Item 3 were different in optical properties from the glass source from Item 1. Therefore, the glass from Item 3 could not be associated with the glass from Item 1. (FRE = 57.7, *fairly difficult*; FK = 9.4).

According to the practice note for expert reports for the Federal Court of Australia (Keane, 2011), results and inferences should be differentiated. Although this requirement undoubtedly applies to the report as a whole, it may be helpful for readers if at least two sentences per comparison are provided in conclusions.

Make inferences and assumptions explicit. A proportion of scientists reported an inference for the positive comparison, and a result without an inference for the negative comparison. Whilst this practice was economical in terms of space, this type of non-parallel sentence structure did not facilitate understanding. If the inference from a finding is not made explicit, it is possible that non-scientists will make incorrect inferences (McNamara & Kintsch, 1996). For this reason, scientists would be encouraged to clearly state the inference from a negative result. For example, “Therefore, in my opinion, the glass from the driver’s seat did not come from the same source as the glass in the kitchen.” However, of course, this should be provided only when the scientist possesses and presents the information upon which the inference is based.

Another text structure resulted when inferences were given by providing a degree of support for a proposition. Two distinct propositions were used in this sample of conclusions. The first was a source level proposition, (which may have been influenced by the wording of Question 1 of the test; see Part 1, Sample), stating that “the glass from the jumper could have come from the glass from the kitchen”. This proposition was similar to the positive inference. The second proposition was an activity level proposition that “the jumper (or the wearer of the jumper) was near the glass in the kitchen at (or after) the time it was breaking.” In most instances, conclusions that presented support for a proposition did so for a positive comparison only. The inference from a negative comparison was presented in the style first described above, or was not provided. This resulted in an unbalanced text structure. More problematic was that the chain of inferences leading to support for the proposition was not made explicit. Providing support for a proposition may be more helpful if it were in addition to the positive finding from a comparison, inference of common source, and statement about the basis for the additional inference supporting the proposition (e.g., case information and calculation of likelihood ratios). The basis for the support for the proposition was provided only in a single conclusion of this type.

A good example of making inferences explicit for the non-scientist reader was found in over one-third of conclusions. In these conclusions, the inference from a positive finding, that the glass from the sweater could have come from the glass from the kitchen, was followed by a statement that other sources of glass were possible. It could be argued that the use of the word *could* in a simple expression such as “A *could* have come from B” may well *imply* that other sources are possible. However, it cannot be assumed that report-users would be aware that identification of a single source is not possible. Therefore, the inclusion of information about the limits of the inference seems potentially helpful to report-readers and worthy of inclusion in the conclusion.

Define unusual or scientific terms in text. The use of unfamiliar, scientific terms within the conclusion presented a potential hurdle for non-scientists. As has been indicated in readability studies of medical information, unfamiliar, scientific terms are not necessarily long words, and therefore this problem may not be accounted for using readability formulas (Paasche-Orlow et al., 2003). Abstract terms (e.g., “optical properties”, “questioned glass particles”, “known glass source”, “associated with”) decrease readability because the reader has to pause to think about what they mean. Concrete terms are more familiar, simpler, and enable the reader to more readily construct a mental image (Britton & Gülgöz, 1991).

In particular, the use of specific terminology may inhibit comprehension when it occurs without descriptions or definitions (Laidlaw et al., 2007). This issue is further compounded when abbreviations or acronyms are used (e.g., “GRIM3”, “ICP/MS”, “nD”, “RI”, “SEM/EDX”, “UV”, “XRF”). We recognise that it is possible that scientists routinely define their terms in the body of the report or in an accompanying glossary. However, for the purposes of understanding a conclusion as a stand-alone piece of text, and arguably the most important part of the report, the use of scientific terms is an important issue. Unfamiliar acronyms are not reader-friendly, even though their use (artificially) lowers readability scores in comparison to the full terms.

Where necessary to use scientific terms, correct scientific terms should be used in full in the first instance in the conclusion, with an in-text definition provided if possible. However, it is worth considering the level of specificity required in a conclusion. It may be that having elaborated upon the instruments and methods in an earlier section of an expert report, a more general or descriptive term would suffice in the conclusion (e.g., “a microscope” rather than “a scanning electron microscope” or “SEM”; “were analysed with our usual methods” rather than “were analysed using inductively Coupled Plasma-Mass Spectrometry [ICP-MS]”).

A range of terms was used by different scientists to express the same idea, reflecting a finding from past research (Jackson, 2009). In the absence of empirical evidence about the rates of misunderstandings based on uses of these expressions, it would not be advisable to advocate restricting the range of expressions to a pre-determined set. Stereotyped expressions may constrain individual scientists in their efforts to explain (Roland, 2009). Instead, scientists are encouraged to consider how the findings in their particular case contexts can be most clearly expressed to the readers of their reports.

To illustrate the point about the respective merits and potential pitfalls of various terms, the example of expressing the finding from a positive comparison is used. A term frequently used to express a positive finding was the 6-syllable word, *indistinguishable*. At the opposite end of the continuum was the use of a 1-syllable word, *same*. Other possible terms included *did not differ*, *consistent*, *alike*, *similar*, and *match* (although *match* was used only twice). The term *indistinguishable* is far more precise in meaning than *same*, suggesting that a (meaningful) difference could not be found, in a way that the word *same* does not. However, if the properties of the object that do not differ are added to the sentence, some of the importance of the nuance captured by *indistinguishable* is lost (e.g., A was the same as B *in refractive index*; A was indistinguishable from B *in refractive index*). Despite this, the precision of meaning of the word *indistinguishable* may be too valuable to discard in favour of a simpler word such as *same*. If so, perhaps it could be accompanied by an in-text explanation of meaning. For example:

> Items A and B were indistinguishable. This means that I did not find any meaningful differences in the two samples of glass when I compared them in colour and refractive index. (FRE = 62.8, *standard*; FK = 8.3)

In this way, both precision and reader ease can be balanced. It is crucial that scientific expert opinion be communicated in such a way that it retains the precision of meaning, and is understood by non-scientists.

Refer to the items compared using concrete terms. Approximately half of the scientists referred to the items tested using scientific terms, either with the item numbers, or with both the item numbers and descriptive terms (see Table 4). This use of scientific terms resulted in a number of potential related issues. First, although the terms *known, control,* and *standard* are not uncommon words, they may be unfamiliar to the non-scientist in the reporting contexts in which they are used. Second, these terms assumed an understanding of laboratory practices of making comparisons between known and unknown samples. Such an understanding cannot be assumed for the non-scientist reader. Third, when these terms were used in sequence with descriptive terms and item numbers, the result was long noun strings, adding unnecessarily to sentence length. Fourth, the use of multiple terms made it necessary for the non-scientist reader to move back and forth through the text to locate the meaning referred to by the item number and the scientific term.

Items were referred to by numbers only, or numbers and scientific terms in just under half of the conclusions. However, the use of descriptive terms in comparison to scientific terms may be preferable to non-scientist audiences, because concrete terms may be represented readily with a mental image (Britton & Gülgöz, 1991). Although consistency of vocabulary is helpful to the reader, descriptive terms could be used in full in the first instance and then shortened for subsequent use. For example, after the first use “the glass from broken glassware from the victim’s kitchen” could be shortened for second and subsequent use to “the glass from the kitchen”.

Using multiple terms to refer to the items compared may reflect laboratory guidelines, or scientists’ attention to detail, and may facilitate communication with other scientists through following established practices. For scientists who typically use the scientific terms without descriptive terms, these could be retained in a contextualising statement prior to reporting findings and inferences. For example, “Item 1, glass from broken glassware in the victim’s kitchen was used as a source control, against which the two questioned glass items were compared.” The following or preceding sentences would incorporate descriptions of the questioned items.

This is not to suggest that item numbers should not be used. Item numbers should be used to ensure continuity, especially in cases with multiple exhibits. However, item numbers were used in several ways that interrupted the flow of sentences in conclusions. These included using item numbers preceded by the hash symbol (#), or by two zeros, item numbers in quotation marks, and item numbers following descriptive and/or scientific terms without punctuation. Rather than referring to items using the item numbers within the text, it would be preferable for item numbers to be in parentheses, following the use of the descriptive terms. For example, “The glass from the kitchen (Item 1)…”. In contrast to this, using the item number in text and its description in parentheses indicated a focus on the number. For example, “Item 1 (the glass from the kitchen) …”. This second approach may be less helpful to the non-scientist reader, as it de-prioritises the concrete terms, making it more difficult to form a mental image.

Implications for Forensic Scientists

It seems plausible that many issues in the readability of texts arise for non-experts because of the expertise of the writer. For example, inferences are not made explicit because the inference-making process has become automatic once someone acquires expert status (Britton & Gülgöz, 1991). Based on the literature reviewed and the readability analyses undertaken in Parts 1 and 2, ten suggestions regarding the writing of conclusions are made, with the aim of increasing the readability of conclusions for non-scientists (see Table 5).

Specific approaches to reporting conclusions that have been developed over time and found to be helpful in the past by individual scientists, certain laboratories or jurisdictions can be maintained when enhancing the readability of conclusions. To write conclusions that are more readable to non-scientist report-users, a scientist would first write a conclusion following the usual procedure and then check the readability statistics. After checking the conclusion against the suggestions in Table 5, for the presence of the features designed to enhance readability, and making adjustments, the scientist could re-check the readability statistics. In this way, scientists would be sure that all information presented in the original was retained (maintaining the scientific integrity of the original), and that readability was enhanced for the non-scientist report-user.

Table 5

Suggestions to Increase the Readability of Conclusions for Non-Scientist Readers

1. Keep in mind a non-scientist reader. Try to achieve a balance between long and short sentences and avoid overuse of the passive voice. Aim for a Grade 7-9 reading level or a Reading Ease score from 60-70 (*standard*). (Readability statistics; sentence structure)
2. Provide a sentence outlining the context or purpose at the beginning, to let the reader know what the scientist did and why. (Coherence and unity)
3. To refer to the items compared, use descriptive terms followed by item numbers in parentheses. (Vocabulary; elaboration; coherence and unity)
4. Provide definitions or explanations within the text for necessary unusual or scientific terms. Avoid the use of acronyms and abbreviations. (Vocabulary; elaboration)
5. Use parallel sentence structures to report positive and negative findings and inferences. (Text structure)
6. Write about findings and inferences in separate sentences. (Sentence structure)
7. Introduce inferences with a link to findings. (Coherence and unity)
8. When making an inference about a possible common origin, state explicitly that an individual source cannot be determined. (Elaboration)
9. When giving support for a proposition, state explicitly the information upon which the support is based. (Elaboration)
10. When using a conclusion scale to convey the degree of support for a proposition, provide the scale and state explicitly the basis for the scale. If it is a subjective conclusion scale, make this clear. (Elaboration)

Note. The elements of texts upon which suggestions are based are in parentheses after each suggestion.

Limitations and Future Research

The focus of this paper was the communication of scientific expert opinion in the conclusions of expert reports (written in proficiency tests). Of course, when addressing issues of readability, it is imperative that scientists be mindful of retaining scientific integrity. Although the interpretation of scientific findings is an issue of great importance, and one closely related to that of communicating the conclusions, a discussion of scientific integrity in forming conclusions was beyond the scope of this paper. The suggestions provided are intended to maintain scientific integrity, assuming that the original conclusion is valid. The suggestions provided cannot transform an invalid conclusion into a valid one.

It was assumed that the language and content used in proficiency test conclusions reflected that of conclusions in actual expert reports. All conclusions were presented as single paragraphs, and the single paragraph structure was retained. In practice, conclusions may span more than a single paragraph. In fact, participants in the proficiency test may not have been able to perform analysis and write conclusions as they normally would for various reasons. The limits of space allocated, and the fact that it was a proficiency test may have meant that the participants wrote briefer conclusions, omitting explanatory material that would ordinarily be included. Participants may have used the terms that they read in the case scenario or in test questions rather than terms they would ordinarily choose. Further research using expert reports written as part of routine casework is currently underway to determine the extent to which conclusions written in proficiency tests reflect those in real reports.

Because the data were limited to conclusions, a more holistic consideration of the reports in full was not possible. Some aspects of qualitative text assessment, such as length, may be more applicable to texts as a whole. It was not possible to take into account qualitative features of texts such as the use of figures, tables, diagrams, illustrations, or photographs, font and font size, or use of white space (Badarudeen & Sabharwal, 2010). It may be that some conclusions analysed here would have been further clarified in light of the report as a whole. Exploration of the readability of reports in their entirety is an area to be addressed in our future research.

The sample in this study consisted of the conclusions written as part of a proficiency test for glass analysis. Because the conclusions of other chemistry sub-disciplines such as paint and fibre analysis have a number of similarities to those of glass analysis, the suggestions presented here may have applications to these sub-disciplines. However, we cannot draw any specific conclusions about reporting practices in any particular jurisdiction, because the conclusions in our sample were from international participants in an anonymous proficiency test.

It was beyond the scope of the present research to test the impact of using language and content according to the suggestions provided on report-users' comprehension of conclusions. Further research is necessary to determine whether the theoretically derived increases in reading ease translate into improved understanding of reports and, ultimately, to improved justice outcomes. It is intended that each of the limitations above will be addressed in the course of the larger research project, of which this study forms one part.

Conclusion

This research began to address the issue of communication of scientific expert opinion to non-scientists through written reports. The conclusions from an international proficiency test for forensic chemists, specifically, glass analysts were used to consider the readability for police investigators, lawyers, and judges. Although written reports are routinely used to communicate findings to non-scientist audiences, in general, the conclusions in this sample were written in a way more suited to readers who have undertaken some tertiary study of science. Based on past research drawn from education, health literacy, and psychology, suggestions were provided to increase the readability of conclusions. These suggestions may be helpful to scientists in meeting their ethical responsibility of ensuring that their expert opinions are understood by the non-scientists who use them to make decisions within the criminal justice system.

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5

The Readability of Expert Reports for Non-Scientist Report-Users: Reports of Forensic Comparison of Glass

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Abstract

Scientific language contains features that may impede understanding for non-scientists. Forensic scientists' written reports are read by police, lawyers, and judges, and thus assessment of readability is warranted. Past studies of readability differed in background theory and approach, but analysed one or more of: content and sequence; language; and format. Using a holistic approach, we assessed the readability of expert reports (*n* = 78) of forensic glass comparison from 7 Australian jurisdictions. Two main audiences for reports were relevant: police and the courts. Reports for police were presented either as a completed form or as a brief legal-style report. Reports for court were less brief and used either legal or scientific styles, with content and formatting features supporting these distinctions. Some jurisdictions prepared a single report to satisfy both the courts and police. In general, item list, analytical techniques, results, notes on interpretation, and conclusions were included in reports of all types. However, some reports omitted analytical techniques, and results and conclusions were sometimes combined. According to Flesch Reading Ease, language was *difficult,* with a Flesch-Kincaid grade level of *university undergraduate*. Sentences were long and contained undefined specialist terms. Information content per clause (lexical density), was typically high, as for other scientific texts. Uncertainty was expressed differently by jurisdiction. Reports from most jurisdictions were cluttered in appearance, with single-line spacing, narrow margins, and gridlines in tables. Simple suggestions, based on theory and past research, are provided to assist scientists to enhance the readability of expert reports for non-scientists.

The Readability of Expert Reports for Non-Scientist Report-Users:

Reports of Forensic Comparison of Glass

Scientists have long provided expert opinion, or interpretations of findings, for use in police investigations and courts (Mnookin, 2001). The difficulties for scientists in explaining their findings and expert opinions to non-scientists have been recognised as a challenge (Roberts, 2009). Traditionally, when using forensic science to inform operational decisions in investigations, police investigators have deferred to the expert knowledge and opinion of forensic scientists. In contrast, judges and jurors have relied upon forensic scientists facilitate their comprehension of, or educate them about, the science relevant to a case, to inform their finding of fact and decision on a verdict (Roberts, 2002). Similarly, lawyers require sufficient understanding of the science to examine and cross-examine effectively the expert witnesses at trial (Cashman & Henning, 2012). But because of the implausibility of jurors (and others) obtaining an adequate understanding of the complexity of forensic science within the context of a specific trial (Roberts, 2009), Mnookin (2001) described the educational approach to communication of expert opinion as a variant of the deferential approach.

In most court cases, forensic scientists are not summonsed to appear, and therefore, are not present to explain their reports (Rothwell, 2010). Furthermore, investigative and pre-trial meetings between scientists and report-users do not always occur (Kelty, Julian, & Ross, 2013). Therefore, enhancing the readability of expert reports is important as part of an approach that aims to address the issue of communicating expert opinion to non-scientists. Readability has been defined as the ease with which a text can be read because of the style of writing (Klare, 1963) or the functionality of a document for its audience in the context of its use (Sand, Eik-Nes, & Loge, 2012).

This paper is the second in a programme of ongoing research that aims to address the issue of the readability of expert reports. Whilst reporting and interpretation are related, our focus is on reporting. The purpose of these papers is to contribute to the international discussion of how best to facilitate comprehension for the non-scientists who use expert reports. The first paper analysed conclusions written as part of an international proficiency test of forensic glass analysis (Howes, Kirkbride, Kelty, Julian, & Kemp, 2013). In the present paper, we explore aspects of the readability of expert reports of forensic comparison of glass written by scientists in Australian jurisdictions,[1] and thus in an adversarial legal system. We describe current reporting practices, analyse holistically their readability, and suggest modifications to enhance readability. The next paper in the series is concerned with the readability of reports of DNA analysis.

Scientific Language

A helpful perspective from which to consider scientific language is offered by the theoretical framework of systemic functional linguistics. In this framework, language is seen as a resource for making meaning in texts and contexts (Halliday & Martin, 1993). The use of scientific language, a specialised language, can be particularly effective when scientists communicate with others from the same field of specialised knowledge (Hagge, 1997). This is because in the process of becoming a scientist, scientists enter a scientific discourse community (Hagge, 1997; Halliday, 1993a) and come to share an understanding of the nature of scientific inquiry and of scientific knowledge.[2] It cannot be said that a

[1] Australian police (and forensic laboratory) services are organised by state (n = 6), territory (n = 1), and federal (n = 1) jurisdictions (Australian Bureau of Statistics, 2012). Each laboratory is accredited to the same standard by a single accrediting body, the National Association of Testing Authorities (NATA).

[2] Although language conventions also exist in policing and law (Eades, 2010), and some overlap could be expected in the forensic science community, the focus of this article is on scientific language conventions, because the scientific language is most likely to pose difficulties for police, lawyers, and judges who use the expert reports. For jurors, language conventions specific to all professions working within the criminal justice system may be unfamiliar to readers; however, jurors are less likely to receive copies of the reports.

shared understanding of science exists between forensic scientists and non-scientist report-users in the criminal justice system. Instead, scientific language can be unfamiliar and alienating to non-scientists and can pose an obstacle in communication from scientists to non-scientists (Halliday & Martin, 1993; Fang, 2005).

According to Halliday (1993b), understanding science is synonymous with understanding the language of science. Four key features of scientific language that make it difficult for non-scientists to understand (Fang, 2005):

(1) *Informational density* (also called lexical density) refers to a high proportion words carrying content (as opposed to fulfilling a grammatical function) in the text (Halliday, 1993b).

(2) *Abstraction* refers to the use of long strings of nouns as the grammatical subjects and objects of sentences (Fang, 2005), and the use of nouns to describe actions that would usually be described in ordinary English by verbs. Moreover, the passive voice is often used, which can result in ambiguity about agency (who or what is responsible for the actions described; Roland, 2009).

(3) *Technicality* refers to the use of both specialised vocabulary and ordinary words with specialist meanings as well as the complex inter-relationships of the specialist terms to each other (Halliday, 1993b).

(4) *Authoritativeness* is communicated through the use of specialist and technical terms, and by the sense of objectivity associated with text written in the third person and the passive voice (Fang, 2005).

In addition to these four features, it has been argued (e.g., Roland, 2009; Horn, 2001) that scientific writing is characterised by hedging, or using words and expressions (such as “may”, “should”, and “probably”) that fall along a continuum of uncertainty or caution regarding a conclusion.

Recently, international debate about expert evidence has focused on this issue of communicating uncertainty. The debate recognises the difficulty of communicating the appropriate degree of uncertainty about expert opinions (with or without the use of statistics), without causing confusion for non-scientists (Aitken, 2012; Berger, Buckleton, Champod, Evett, & Jackson, 2011; Ligertwood & Edmond, 2012a). Providing only a statement that two fragments of glass *could have* come from the same source is seen as a simplistic approach (Aitken, 2012) that does not communicate the significance of the evidence. Yet communicating uncertainty, with what is known as the "logically correct" approach (Berger, 2010), using likelihood ratios, can pose difficulties for scientists and non-scientists (including judges and lawyers) alike (de Keijser & Elffers, 2012). Ligertwood and Edmond (2012b) suggested reporting simple frequencies rather than likelihood ratios to avoid confusion for judges and jurors. They argued that scientists' preference for using likelihood ratios, particularly when presented in numerical form, but also as verbal scales, could lead to misunderstandings for non-scientists, such as the prosecutor's fallacy (that the number or term expressing the likelihood ratio equated to the probability that the suspect left the trace).[3] While this debate ensues, some of the less contentious aspects of readability could be addressed.

Approaches to Assessing Readability

As outlined below, a great deal of past research on readability assessment has been within the field of patient education and health literacy, in which practitioners communicate with a lay audience. In addition, studies on readability of written communication from professionals in one discipline to another, as is the case in the criminal justice system, have included psychologists' reports on students for use by teachers. Although the communication in these contexts is less likely to be contested than

[3] In contrast, the scientist expresses an opinion on the probability of the findings given the propositions. Critically, the scientist comments on whether the suspect left the trace versus had nothing to do with the incident, not on the probability of the propositions given the finding.

is the communication of forensic science in the criminal justice system, the methods used to assess the readability of texts can be applied to expert reports.

Approaches to assessing the readability of texts include the use of formulas to quantify textual features (Benjamin, 2012), and more descriptive approaches to content analysis to illustrate these features (e.g., Clerehan, Buchbinder, & Moodie, 2005). Formulas can be used to calculate: the lexical density of a text (Halliday, 1993b; Eggins, 1994; Gholami, Mosalli, & Nikou, 2012); the reading ease of a text (Flesch, 1948; 1949); the number of years of schooling based on the US education system required to read a text (Kincaid, Fishburne, Rogers, & Chissom, 1975); and the difficulty of documents that present information in matrix form, such as lists, tables, and graphs (Mosenthal & Kirsch, 1998).

In addition to quantitative approaches, content analysis offers a systematic, exploratory method (Berelson, 1952; Krippendorff, 2004) to identify trends in written communication of groups or institutions (Babbie, 2010; Sproule, 2010). The categories for coding can be derived from the text itself or directed by existing style guides,[4] theory, or past research (Berg, 2009; Hsieh & Shannon, 2005). Coding generally covers all relevant aspects of data, minimises overlap and ambiguities, and produces a coherent breakdown of content (Sproule, 2010). The process of coding usually involves quantifying features of text for presence or frequency of occurrence (Babbie, 2010), but can incorporate a blend of numerical and descriptive analysis (Berg, 2009).

Despite diverse theoretical origins, a number of striking similarities and areas of overlap are evident in the approaches to readability assessment outlined above. These are

[4] Although no definitive style guide exists for writing expert reports, it is reasonable to expect that forensic scientists would be influenced by the writing conventions of the broad scientific discourse community. This includes the styles used in scientific journals (such as the use of the IMRAD – introduction, method, results, and discussion format; Wu, 2011); the wording and expressions alluded to in the forensic science discourse community, including disciplinary and sub-disciplinary handbooks (e.g., Curran, Hicks, & Buckleton, 2000), and seminal articles (e.g., Evett, Jackson, Lambert, & McCrossan, 2000); and the specific in-house laboratory styles (Rothwell, 2010). Furthermore, for forensic scientists, there exists overlap between scientific, policing, and legal discourses. Scientists would necessarily be influenced by legal requirements, such as practice directions on the form and content of expert reports (e.g., Keane, 2011).

summarised in Table 1. All of these approaches to content analysis coded texts in one or more of three broad categories: (1) content and sequence; (2) language; and (3) format. As with formulas, which assess one aspect of readability (e.g., Flesch-Kincaid grade level assesses aspects of language; the PMose/IKirsch document readability formula assesses aspects of format), at times researchers may focus on one or two of these broad categories (e.g., Donders, 2001a; Donders, 2001b; Shrank, Avorn, Rolon, & Shekelle, 2007). Holistic and inclusive approaches to readability assessment are characterised by consideration of all three broad categories: content and sequence; language; and format.

Current Study

The purpose of this study was to identify the key features of content and sequence, language, and format of expert reports across jurisdictions. Because of the dearth of research in this area, we aimed to incorporate a number of readability assessments to provide a comprehensive overview of the readability of expert reports. The research was exploratory in nature and no specific hypotheses were made. We aimed to determine whether the readability of conclusions from Australian expert reports of glass comparison differed from that of the conclusions of international proficiency tests (examined in our previous study, see Howes et al., 2013). To contribute to the current debate about the communication of uncertainty, we considered the form of expression of scientists' opinion in Australian jurisdictions for forensic comparison of glass. Next, we ascertained whether the conceptual content of expert reports was organised consistently across jurisdictions. We identified aspects of the content and sequence, language, and format of expert reports that might pose particular readability issues for non-scientist report-users and suggested ways to address them. At this stage of our investigation, we have not tested report-users' responses to current reports or reports that have been modified in line with our suggestions for improved readability.

Table 1

Summary of Concepts Considered in Quantitative and Qualitative Approaches to the Assessment of Readability by Key Category

			Key Categories[a]		
Approach	Approach based on	Researchers	Content and sequence	Language	Format
Lexical density	Counts (used in systemic functional linguistics) associated with different contexts of language use (e.g., standard spoken or written English, scientific English)	Halliday (1993b), Eggins (1994)	NA	Information-carrying content words per clause	NA
Flesch Reading Ease, Flesch-Kincaid Grade level	Counts (sentence level features) equated with a reading ease score or a grade level	Flesch (1948; 1949) Kincaid et al. (1975)	NA	Number of words, number of sentences, number of syllables (proportion of sentences in passive voice is also provided by Microsoft Word 2010)	NA
PMose/IKirsch Document Readability Formula	Counts (of features of lists and tables) converted to a score and equated with a grade level	Mosenthal and Kirsch (1998)	NA	NA	Scores assigned and summed for complexity and density of matrix structures used in a document
Evaluative linguistic framework (systemic functional linguistics)	Qualitative analysis of nine categories (including lexical density) to describe texts before recommending modifications	Clerehan et al. (2005), used to evaluate patient education leaflets	Organisational structure, rhetorical elements, meta-discourse, factual content of text	Technicality of vocabulary, lexical density (as above), relationship between the writer and the reader	Headings, format

Table 1 continues overleaf

Table 1 continued

Approach	Approach based on	Researchers	Key Categories[a]		
			Content and sequence	Language	Format
Human factors design	Three key principles used to assess and modify texts. (Readability formulas used to support this.)	Feufel, Schneider, and Berkel (2010), used to assess and re-design medical test instructions	Use-centred content and organisation	Language comprehensibility	User-centred presentation
Educational and psychological research	Six features inherent in text and four features emphasising interaction between the reader and the text.	Graves and Graves (2003), used to select appropriate reading material for students	Text structure, coherence and unity, background knowledge required	Sentence structure, vocabulary, elaboration, audience appropriateness, quality and verve of the writing, interestingness	Length
Suitability Assessment of Materials (based on educational and psychological research)	Checklist to assess texts and modify those aspects with low scores.	Doak, Doak and Root (1996), used to assess and modify patient education materials	Content, learning stimulation and motivation, cultural appropriateness	Literacy demand	Graphics, layout and typography

Note. Quantitative approaches include formulas and counts; qualitative approaches include theory-driven and research-informed content analyses.
[a]In assessing readability, knowledge of the needs of the target audience informs all three key categories.

Method

Sampling Procedure

Letters introducing the research and information sheets were sent via email to the laboratory directors of forensic laboratories in all eight Australian jurisdictions. Specifically, laboratories specialising in forensic chemistry (glass comparison) were invited to participate in the research. Participating laboratories were asked to send (electronically) 10-15 recently written, de-identified (redacted) reports of glass comparison from different case types to show the range of reporting styles used in their labs. The rationale for requesting 10-15 reports was to use the individual report as the unit of observation, to attempt to cover the range of reporting styles for jurisdictions, and to ensure that features anomalous to a particular report would not be coded as general features of the report type (the unit of analysis).

Sample

Seven Australian forensic laboratories undertake forensic glass comparison and all seven laboratory directors indicated their willingness to participate in the research. Because the unit of analysis was the expert report by jurisdiction, laboratories were each assigned a letter from A to G, in no particular order, to maintain anonymity. Each report received was assigned a number. Eighty-one reports were received in total consisting of a sample of between 9 and 16 reports from each laboratory. Three reports in total were excluded from analysis. Two reports were excluded because they were reports of forensic analysis of paint, whereas we had specifically requested reports of forensic comparison of glass. One report was excluded because the page containing the conclusion was missing. The resulting sample consisted of a total of 78 expert reports of glass comparison.

The reports received from laboratories included some short reports intended for police investigators (Jurisdictions D, E, F, & G) and longer reports intended for use by the courts

(Jurisdictions A, B, C, D, F, & G). The laboratories in three jurisdictions (D, F, & G) provided both types of reports (see Figure 1). Not all jurisdictions routinely used different reports for police and the courts. The contact scientist at one laboratory indicated that the reports issued to police were often sufficient for the courts within that jurisdiction, but that more detailed reports were sometimes issued upon request. Conversely, the contact scientist in another jurisdiction stated that the reports were issued to police in the format appropriate for use in court, should the need arise.

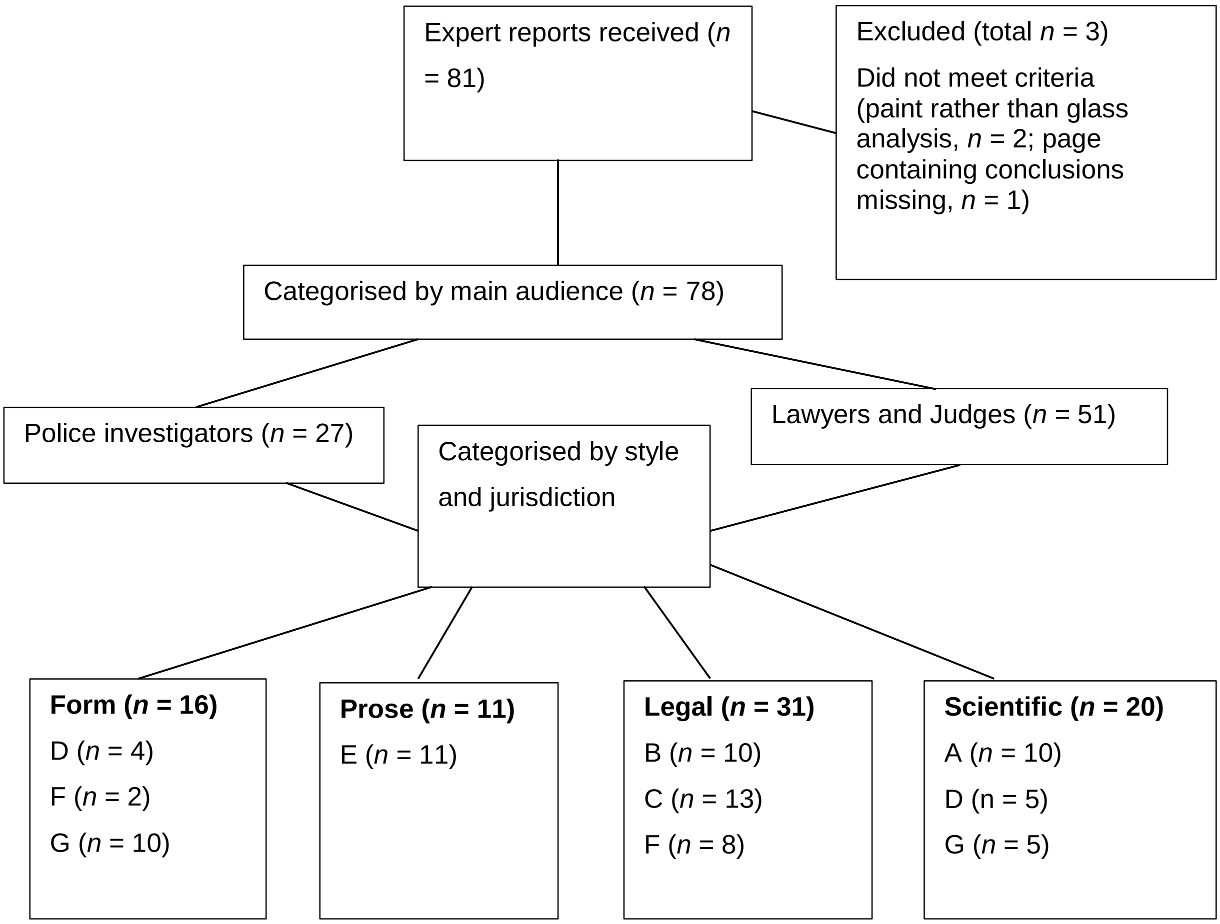

Figure 1. Preliminary analysis: Categorisation of expert reports by main audience, style, and jurisdiction.

Materials

Content analysis. To analyse the readability of expert reports in their entirety, we used an inclusive and directed approach to content analysis (Berg, 2009; Hsieh & Shannon, 2005). We used three overarching categories: content and sequence; language; and format. To these categories, we added specific subcategories and items identified in the past research on readability outlined in Table 1. This is in keeping with the model offered by systemic functional linguistics, which is intentionally broad and inclusive (Halliday & Martin, 1993).

In the category of content, we considered both legal and scientific reporting conventions as influences on reporting in the forensic sciences. In the category of language, we included readability statistics and lexical density (described separately below). In the category of format, we included the PMose/IKirsch document readability formula (for lists and tables included in the documents).

Within this body of items, significant overlap was evident. We deleted duplicates of items. Notes made on the textual features of reports from each jurisdiction during the preliminary stage of analysis formed part of the data corpus and were useful in identifying potential new subcategories and items to consider. Further items were added during the iterative process of reading, re-reading, coding and re-coding the documents. The final list of categories, subcategories, and items is shown in Table 2.

Table 2

Categories, Subcategories, and Items Coded and Described in the Assessment of Readability of Expert Reports

		Guide for observations
Category	Subcategories	Items coded for presence and/or described
Content and sequence	Reader orientation	Summary, purpose of report/examinations, nature of case, case context
	Meta-discourse	Case reference numbers, information about use of the report, contact details, accreditation details, signatures, dates, relevant legal acts, relevant scientific protocols
	Main concepts and sequence	Specialised knowledge of scientist, item list, item custody (and dispatch) information, methods of analysis/analytical techniques, results, notes on interpretation/discussion, conclusion/s, references, glossary, other appendix
	Coherence (links and flow)	Links or logical flow between sections, old information before new (can also be observed at sentence level with proposition overlap)
	Dependence of text on appendix	Glossary, other appendix, appendix mentioned in body of report
	Elaboration of important content	References, limitations of techniques used, background information provided, case relevant information, database information, notes on interpretation, separate results and conclusions
Language	Tone of writing	Formality, passive or active voice, use of first person, different tone in different parts of report
	Technicality of vocabulary	In-text definitions, glossary provided, abbreviations or acronyms expanded
	*Readability statistics	Number of sentences per paragraph, number of words per sentence, proportion of sentences in passive voice; Flesch-Kincaid grade level; Flesch Reading Ease
	*Lexical density	Number of content words per conclusion as a proportion of total words
	Uncertainty	Use of *could,* or other expression, likelihood ratio, scale provided, scale explained
Format	Length of reports	Number of pages
	Information chunking	Use of paragraphs (numbered, indented, number of sentences per paragraph)
		Use of headings and subheadings (concise headings in lay terms, consistent headings used)
	Fonts	Consistent use of fonts, footed font used, at least 12 point font, use of bold for headings and subheadings (not all upper case letters or italics)
	White space	Line spacing, margin size, headers and footers, visible gridlines in lists and tables
	*PMose/IKirsch document readability	Structure and density of lists and tables

Note. The categories and items were derived from theory and past research about readability (see Table 1), from documents informing the contents of expert reports, and from items observed in the expert reports.

Readability statistics. To analyse conclusions only, we used the readability statistics provided by Microsoft Word 2010. Specifically, we recorded the number of sentences per paragraph; the number of words per sentence; the proportion of sentences in the passive voice, Flesch Reading Ease score; and the Flesch-Kincaid grade level. Formulas for calculation of the Flesch Reading Ease (FRE) and Flesch-Kincaid (FK) grade scores are as follows: FRE = 206.835 – 1.015(total words/total sentences) – 84.6(total syllables/total words). FK = 0.39(total words/total sentences) + 11.8(total syllables/total words) – 15.59 (Flesch, 1948).

Lexical density. Due to the time-consuming nature of identifying content words, lexical density was calculated for parts of document only (conclusions), as has been the case in past research (Clerehan et al., 2005; Hirsh, Clerehan, Staples, Osborne, & Buchbinder, 2009). Some researchers have calculated lexical density as the number of content words per clause as suggested by Halliday (1993b). Others (e.g., Gholami et al., 2012) have used the proportion of content to total words (as suggested by Eggins, 1994). As it was unclear which approach to lexical density would be most suitable for our purposes, we opted to use both, with the additional aim of determining whether one measure was more appropriate in the context of expert reports. Using both measures also ensured that our results could be compared to those of other researchers, whichever calculation they had used. The content words were highlighted and counted by hand. The main clauses were identified and counted. Total words in the selection were counted in Microsoft Word, and lexical density scores were calculated (content words/total words in conclusion × 100) and (content words/number of clauses).

PMose/IKirsch document readability formula. To measure the structure and density of lists and tables we used the PMose/IKirsch document readability formula (Mosenthal & Kirsch, 1998). Structure consists of one of four different matrix structures: simple (list with single column heading or label); combined (table/list with multiple column labels); intersected (table with multiple column and row labels); and nested (table with column and row labels and micro-labels or subheadings; Mosenthal & Kirsch, 1998). Density consists of three subcategories: (1) the number of labels or headings for columns and rows of the document; (2) the number of subheadings or micro-labels and items (each cell is one item, but where cells contain text, each clause is counted as an item); and (3) dependency of the list or table on other information such as table notes. The points allocated for structure and density are summarised in Table 3. Correspondence between scores obtained and grade levels are presented in Table 4, where an example of calculation is provided in a table note. For each expert report, the structure of each matrix was first identified before density was calculated using Table 3 and converted to grade scores using Table 4.

Table 3

Scores for Categories of Document Complexity Using the PMOSE/IKIRSCH Document Readability Formula

Scores assigned to each scoring category and subcategory	Scoring Categories			
	Document Structure	Document Density		
		Labels (main table headings)	Items (including micro-labels)	Dependency
1	Simple list	≤ 15	≤ 75	Add 1 for references within the document to table notes or other documents
2	Combined list	16-25	76-125	
3	Intersected list	26-35	126-175	
4	Nested list	36-46	176-225	
5	-	≥ 47	≥ 226	

Note. The category of structure and three subcategories of density are scored using the left-hand column. Scores are then summed to give a document complexity score (Mosenthal & Kirsch, 1998). See Table 4 to convert document scores to complexity levels and the corresponding grade score equivalents.

Table 4

Interpretation of Document Scores as Complexity Levels and Grade Equivalents

Document Complexity Level	Document Scores	Grade Equivalents (in terms of NAEP reading scale)[a]
1	3-5	Grade 4 to less than 8 years of schooling
2	6-8	Grade 8 to a completion of high school
3	9-11	Grade 12 to some post-secondary education
4	12-14	Some university to undergraduate degree
5	15-17	Undergraduate degree to postgraduate degree

Note. For example, Table 4 has a combined list structure (score 1), with three headings or labels (score 1), and 15 items (score 1), and two dependencies or table notes (score 2). These scores total 5, giving a document complexity score of 1, and a grade level of 4-7.
[a](Mosenthal & Kirsch, 1998).

Data Preparation

For readability statistics and lexical density. The conclusions of each report were identified (either from their subheading "conclusions", or because the text reflected the inferences made on the basis of results). The conclusions were pasted into a table in a Word document. Although some conclusions were clearly identified as a distinct section of the report, others appeared throughout the document because such reports presented results of analysis and conclusions in an item-by-item format.

Next, the conclusions were prepared for analysis. Paragraph numbers and subheadings contained within the conclusions, where present, were deleted. Long strings of numbers used in the text of conclusions (e.g., item numbers, or case numbers) were replaced with single-digit numbers (for comparison with proficiency test conclusions; Howes et al., 2013). This decreased the number of characters, but not the numbers of words or sentences, in a given conclusion, and was necessary to ensure that the readability scores obtained would reflect the use of words rather than numbers. (In addition, the use of long strings of numbers can inflate readability scores, such that the ceiling score is reached, making comparisons meaningless.)

Because we had requested that laboratories provide de-identified reports, but had not specified how to de-identify them, identifiable information (such as names, numberplates and addresses) in the conclusions from some laboratories had been replaced with filler items (such as “the victim”, “the suspect”, “Suspect A”). Some laboratories had replaced identifiable information with “xx”, blackened it, or left it blank. To ensure consistency, where an item of text has been deleted for the purpose of de-identification and not replaced, it was replaced with a filler item used by other laboratories. Filler items retained the flow of sentences and more accurately reconstructed the text in terms of word counts, keeping other factors such as the use of passive voice the same.

Results

The categorisation of reports shown in Figure 1 was supported by a preliminary content analysis of the concepts contained in the report and their organisational structure. Features that aided this categorisation included, in reports intended for police, the presence of an explicit statement that the report was intended for police. In reports for court, but not for police, additional item custody information (such as the date of receipt of items) was typically included. Formatting features supported the use of these two main audience categories. For example, reports for police were typically 1-2 pages in length whereas reports intended for court ranged in length from 2-6 pages.

The reports for each intended audience (police and court) were further categorised by style. Most reports intended for police appeared to be written in text boxes in pre-formatted forms. In one jurisdiction (where reports issued to police were reportedly usually sufficient for the courts) a prose format rather than a box format was used.

Reports for use in court were written in two main styles: legal (3 jurisdictions) and scientific (3 jurisdictions). Reports in the legal style contained information about the specialised knowledge of the scientist and a statement that the information contained was true and correct. The use of headings such as “methods of analysis”, “results of examination”, and “conclusions”, and the inclusion of lists or tables with visible gridlines were typical of reports written in a scientific style, although headings were also used in legal style in one jurisdiction. A statement, outlining the specialised knowledge and experience of the scientist, was sometimes attached to a scientific report to make it suitable for use in court. With a statement attached, reports could perhaps be described as a hybrid style.

Results of the more detailed analyses of the readability of expert reports are presented below by category (content, language, and format).

Content and Sequence

Main concepts and sequence. The main sections and sequence included in different report styles are presented in Table 5. Sections frequently included in reports intended for police and reports intended for courts were: items; analytical techniques; results of examinations; and conclusions. Conclusions were often preceded or followed by notes on interpretation. Although the same core sections (items, analytical techniques, results, notes on interpretation, and conclusions) were included in reports for courts and reports for police, the reports for courts tended to provide more detail. The sequence of sections was very similar across jurisdictions, although the position of notes on interpretation varied by jurisdiction (see Table 5). Reports for court in legal style contained a specific section for the specialised knowledge of the scientist, but reports for courts in scientific style did not.

In reports intended for police, reference was made to the purpose of examinations, or the request submitted with items for examination. In some reports for police, notes (to police investigators, without being specifically identified as such) were included about issues with the items submitted for analysis. Suggestions were made to improve future evidence submissions (e.g., a control sample should be included; clothing would be preferred over shoes; items that had been washed and subsequently retrieved from washing lines by police would be unlikely to have retained glass fragments).

Links or flow. Links were not made explicitly between sections, but especially in the reports for use in court, the sections typically followed a logical sequence. A gap in the logic of the sequence occurred in reports of two jurisdictions, because no mention was made of analytical techniques. In reports from one jurisdiction, the techniques were mentioned but not explained. In reports from another jurisdiction, the explanation of analytical techniques was presented in an appendix.

Assumptions about reader knowledge were apparent in many reports. Limited evidence was found of the use of overlapping propositions, or the use of old (previously introduced) information to build new information. One example of a jump in logic that occurred across jurisdictions was when a conclusion was phrased as support or lack of support for a given proposition. The propositions considered were generally not mentioned in a previous section of the report. Where conclusion scales were provided, their numerical basis was not explained.

Table 5

Main Features of Expert Reports by Report Type, Jurisdiction, and Style

Section	Present in Reports		Explanatory notes
	For police	For court	
Specialised knowledge	NA	legal style (B, C, & F)	Consisted of educational qualifications and relevant laboratory employment experience.
Scientist and use of assistants	NA	Scientific style (G)	States that the examination was carried out by the scientist named on the report, or with the help of specified assistants.
Items/Exhibits	All jurisdictions' reports		Consisted of item numbers and brief description of item In addition, reports for court in both styles sometimes contained custody information such as dates received (B, C, D, F & G), label information (A, E, & G), police officer received from (C & F), storage information (D & G), scenes, suspects, or incidents associated with the items (C & G). Reports for police sometimes included information about the scenes, suspects, or incidents associated with items (G).
Request for examination and/or Purpose of examination	F and G	A, B, C, F, and G	Reports for court with requests often included the date of request (F & G)
Analytic techniques	D, F, and G	A, C, D, F, and G	Explanation of analytic techniques was usually provided (C, D, F, & G). Jurisdiction A's reports listed the techniques but did not explain them. Explanation were located in an appendix (G)

Table 5 continues overleaf

Table 5 continued

Results of analysis	All jurisdictions' reports		Usually included both descriptive results by item, and the results of comparisons. Sometimes presented by suspect.
			Combined with conclusions (B, E, sometimes combined in reports for police of G)
Notes on interpretation	All jurisdictions' reports		This section preceded conclusions (A & B), followed conclusions (D, E, & G), occurred in analytical techniques section (C), or was presented throughout the report as pertinent (F). Information included varied by jurisdiction more than by case. Examples of information included were case information received from police, studies of transfer and persistence, references, use of database, limitations of RI, database search.
Conclusions	All jurisdictions' reports		Not always separate section from results. Some used a scale to express support for a proposition (A, sometimes B, always D, F, & mostly G). Scale provided (D & F). Stated that the basis for the scale was a likelihood ratio (D). "Could have" (mostly B, always C, sometimes G); "may share a common origin" (E).
Appendix	NA	C and G	Glossary of terms (C).
			Explanations of methods and some notes on interpretation (G).
Statement of truth	NA	Legal style (B, C, & F)	States that the information contained is true and correct to the best of the knowledge of the scientist.

Note. Relevant jurisdictions are referred to in parentheses.

Reader orientation. None of the expert reports included a summary or abstract. However, the expert reports for court from one jurisdiction included a table of contents on a cover page of the (scientific-style) report. In most expert reports the nature of the case was referred to only in the title of the report. Case contextual information was not provided in reports for police investigators, but nor was contextual information provided in most of the reports intended for use in court. Only one jurisdiction routinely included the context of the case, typically providing approximately one paragraph of information on the context of the case that the scientist had received from police investigators. Information about the purpose of the examinations was usually provided, in all but two jurisdictions, but was restricted to a single sentence.

Meta-discourse. In reports for police, the meta-discourse included official information such as the police jurisdiction and logo, police and laboratory case reference numbers, scientist name, police investigator name, laboratory contact details, and page number (as "page 1 of *n*"). The fact that the report was intended for use by police investigators was noted on the report, and readers were advised that a more detailed version for use in court could be obtained by request.

The meta-discourse of reports for courts included official information such as laboratory and police case reference details; and National Association of Test Authorities (NATA) accreditation information, including the NATA symbol and the NATA accreditation number. Official information about use of the document was sometimes included and consisted of advice that the document should not be reproduced except in full, or that its contents should not be disclosed except with permission. The reports for police of one jurisdiction, which were often used in court, also included NATA accreditation details. The use of the logo of the police jurisdiction and the NATA symbol could be seen to add to the official tone of the documents and increased the sense of authority of the messages contained within.

In addition, in reports for court in legal style, information was included about relevant legal acts or information that had been read prior to preparation of the reports. Almost all reports for courts and for police had space for the signature of the scientist; and some reports for court (in legal style and in one jurisdiction with scientific style) had space for the signature of a witness.

Dependence of text on appendix. One jurisdiction's reports for court contained an appendix explaining the methods of glass analysis. One jurisdiction's report for court (legal type) contained an appendix of a glossary of terms. The glossary was not referred to in the body of the report. The report for court of one jurisdiction contained a statement as an appendix, and this was where the specialist knowledge and experience of the scientist was outlined.

Elaboration of important content. The reports for both police and courts from some jurisdictions did not separate the results and conclusions sections. For reports for court, one jurisdiction (scientific style) provided references to the information upon which interpretation was based. Notes on interpretation, although not necessarily constituting a separate section of the expert reports, were present in most reports and differed more by jurisdiction than by case, suggesting that laboratories prepared generic notes and scientists supplemented them with case-specific notes where necessary. One jurisdiction routinely provided database information (the results of a database search for matching glass), while another sometimes included it.

Language

Tone of writing. The tone of writing was formal and informative. Although in most jurisdictions the active voice was used to report findings, the use of the first person was limited to specific places within the document. The first person was used to state opinions and scientific qualifications. Legal style expert reports contained more use of the first person than did other reports, because the first person was used both to describe specialist experience and in conclusions. In addition, reports for court of one jurisdiction contained notes on interpretation expressed in the first person of what the scientist would or would not expect to find, based on their specialised knowledge and experience (e.g., research on persistence of glass on fabric over time).

Language in meta-discourse about document use was official in its tone. This tone was accomplished by using terms such as “must not”, “permission”. Some elements had a formal legal tone, referring to sections of relevant laws.

Technicality of vocabulary. The vocabulary used in reports was highly specialised. Terms were often not defined. This lack of definition applied to both scientific terms and to non-specialist words used with specialist meanings. This was apparent in the methods of analysis section, where scientific techniques were listed without explanation. Scientific terms, (such as *refractive index*, *stereomicroscope,* and *oil immersion method*) were often not explained. Acronyms (*RI*, *GRIM 3*) were sometimes not expanded or explained. Non-scientific terms used with specialist meanings (e.g., *matching and non-matching groups*, and *control sample*) were often not defined, nor were the meanings of the relationships between the terms explained.

Readability statistics. Paragraphs of 1-2 sentences were most common in the conclusions of expert reports. The exception was the prose police reports of one jurisdiction, which tended to use 3 sentences per paragraph. The sentences in such reports were the shortest, but nevertheless contained over 21 words on average. Sentences, in general, were long with one jurisdiction's conclusions consisting of sentences of over 46 words on average. Regardless of the intended audience, reports were predominantly written at a level considered *difficult*, with only the prose reports for police from Jurisdiction E, and the scientific-style reports for courts from Jurisdiction D written at the less difficult level of *fairly difficult*. The Flesch-Kincaid grade scores indicated that undergraduate or postgraduate university education was required to read the conclusions. The only exception to this was Jurisdiction E's reports, which were suitable for readers with a senior high school education.

Lexical density. The mean lexical density of conclusions is presented by main audience, report type, and jurisdiction in Table 6. Reports for police and for courts had lexical density of around 50% (i.e., a 1:1 ratio of content words to non-content words). The range of lexical density was slightly lower for reports for police (38-51%, or 4-10 content words per clause) than for reports for the courts (41-55%, or 6-11 content words per clause). The reports for police and for courts of Jurisdiction D had the lowest lexical density, while Jurisdiction G's reports for police and for the courts had the highest lexical density.

Using lexical density as content words per clause, it was clear that the least dense conclusions (with scores below 6, similar to non-scientific written English) were provided by Jurisdiction D, regardless of report audience. Two jurisdictions had scores between 7 and 8. The most lexically dense conclusions (with scores above 10, as for scientific English) were provided by four jurisdictions. Closer examination of the language used in conclusions revealed that the long sentences often contained embedded clauses (e.g., a clause used as an adjective to describe an item). Embedded clauses allowed scientists to describe in a single sentence the items examined and their relationships to control items. However, embedded clauses may be difficult for readers to understand.

Table 6

Mean Lexical Density, Grade Level of Matrices, and Length of Expert Reports of Glass Analysis by Main Audience, Report Style, and Jurisdiction

Main Audience / Report Style	Jurisdiction	Number of reports	Lexical density of conclusions: Lexical words per clause	Lexical density of conclusions: Lexical words as % of total	Length of report (pages)	Grade level of matrices[a]
			Mean Scores			
Police						
Form	D	4	4.04	38	1.3	4-7
	F	2	7.25	46	1.5	4-7
	G	10	10.05	51	2.4	4-7
Prose	E	11	8.38	50	1.8	4-7 in text; 8-12 for results in table occasionally
Court						
Legal	B	10	11.10	46	2.1	4-7 in text
	C	13	10.84	48	3.7	4-7 in text
	F	8	6.71	46	4.0	4-7 in text
Scientific	D	5	5.63	41	2.8	4-7 in text; 8-12 for results tables occasionally
	A	10	10.79	50	2.6	4-7
	G	5	11.35	55	5.0	4-7 in text or table; 8-12 for results tables occasionally

Note. [a]"in text" indicates that the table contained no gridlines. Lists of items presented in text either formed part of a paragraph as bulleted points, or each item formed a paragraph

Uncertainty. Jurisdictions differed in their expression of uncertainty in expert opinion. Four jurisdictions expressed support for a proposition using a scale. One expressed support for a proposition in some reports. The scale itself was provided only by two jurisdictions, and the basis for the scale was provided only by one jurisdiction. Of jurisdictions that did not provide expert opinion as support for a proposition, one jurisdiction mainly used *"could have originated from…"*, one used *"could have originated from…"* exclusively. Another jurisdiction used *"may share a common origin"*. One jurisdiction that provided support for a proposition in the conclusion sections of reports, used *could* in results sections. No jurisdictions expressed evidence in terms of support for one hypothesis compared to another, as is suggested by proponents of the "logically correct" approach. When used, propositions were predominantly at the source level; activity level propositions were present in fewer reports.

Format

Length of reports. Mean report length is presented by main report audience, report type and jurisdiction in Table 6. On average, reports for police were shorter than reports for the courts. This was also true for the three jurisdictions that provided both reports for police and for courts.

Information chunking. In all report types, information was grouped into paragraphs. However, the paragraphs often consisted of single (very long) sentences. Paragraphs were not indented. In reports intended for court (but not for police), paragraphs were often numbered. The numbering styles, where present, differed by report style. In the legal style, paragraphs were numbered sequentially throughout the report, while in the scientific style they were numbered by section (e.g., *"1. Custody of items, 1.1 Receipt of items,.."*).

Headings. Reports for police made use of headings mainly in the boxes at the top of the form containing meta-discourse such as case numbers. In the form style of reports, headings (such as *"items"* and *"results and conclusions"*) were used at the top of the box containing body text. Within the body text, sometimes a heading such as *"conclusion"* or *"notes"* was used, but this use was not consistent across reports or jurisdictions.

Headings were more likely to be used within the body of the reports intended for court, particularly in the in scientific style, but sometimes in the legal style (one jurisdiction). The most consistent use of headings was applied in the scientific style of reports. The headings were typically appropriate in terms of wording, although those that contained more than three words were less helpful than concise headings (because they became more like another sentence to read than a signpost). The most easily identifiable, and therefore the most ideal headings were presented in bold text. Readability was enhanced by use of sentence case as opposed to upper case letters. In two jurisdictions, headings consisting of all upper case letters were used.

White space. White space was somewhat limited in most expert reports (both for police and for court) because lines of text were single spaced. Although there was an extra line between paragraphs, text appeared crowded and cluttered due to the single line spacing. For shorter reports intended for court, often the space *between* (but not within) paragraphs or sections was increased to several line spaces. For longer reports, the space between paragraphs was restricted to a single line space. Similarly, within lists and tables, line spacing was cramped. By contrast, in legal style reports for court, one jurisdiction used 1.5 line spacing, and another jurisdiction used 2.0 line spacing, adding visual appeal and reader-accessibility to text through the presence of more white space on the page.

Margins of reports intended for police in the form style were generally set at the default setting (2.54cm) or slightly narrower (e.g., 2cm); but were set at the default setting or slightly wider in prose style (e.g., 3cm). Margins were generally set at the default setting or greater in reports for court (scientific style). In reports for court (legal style) the margins were narrow on the sides. Margins did not always contribute to white space as headers and footers were frequently used, adding to clutter on the page. One jurisdiction used a grey font in the footer, and this reduced the appearance of clutter. Some reports had lines between the body text and the header and footer, adding to clutter.

Lists and tables that used thick black gridlines or black header boxes with white text (in some reports of one jurisdiction) looked more cluttered. Many lists and tables contained text in single line spacing and had visible black lines. Similarly, in the reports for police, boxes were used to contain meta-discourse, such as official case information. When a box with gridlines (both external and internal) was used, the appearance was cluttered. The reports of one jurisdiction eliminated vertical gridlines from the meta-discourse box, creating a far less cluttered appearance.

Font. The reports of four jurisdictions used Times New Roman (or a similar footed font). Two jurisdictions used Arial (or a similar sans serif font). One jurisdiction had reports in both serif and sans serif fonts. Font size was usually 11-point, and less commonly 12-point. However, sometimes font size was smaller in certain sections of the reports, such as for case number information at the top of reports, and could be as small as 9- or 10-point font. This was more common in reports for police.

Structure and density of lists and tables. Figures were used in only 2 reports, and are not considered further. The mean scores for structure and density of tables and lists by main audience, report type and jurisdiction are presented in Table 6. Lists and tables presented in a matrix style were used predominantly in reports for court written in the scientific style. Legal-style reports for court used a paragraph style as did prose reports for police. Most form-style reports for police used a simple list structure within a column on the left-hand side of the form, although the reports for police of one jurisdiction used a combined list structure (table) without gridlines. Larger scientific reports for court sometimes contained an intersected list structure (table) summarising the numbers of glass fragments located on various items examined, or a summary of different but interrelated cases and the requests for examination of items associated with each. The lists and tables used were predominantly simple or combined list structures, with corresponding grade scores in primary or high school. The structure and density of most of these lists and tables would not be expected to have a negative an impact on readability, even for readers with fairly low levels of document literacy.

However, many of columns in lists and tables lacked headings, as did the tables themselves. When headings were provided their meanings were not always clear, due to use of specialist terms. This lack of clarity was an issue for tables of results in particular. The use of long item numbers in the same column as item descriptions and abundant gridlines may impact upon readability more than would the use of a matrix structure.

Discussion

We discuss below how the results of readability analyses addressed the research questions of: (1) how the difficulty of conclusions of expert reports compared with those written as part of a proficiency test of glass analysis; (2) whether current practice in Australian jurisdictions revealed a preference for a particular way of reporting uncertainty; (3) whether report content was organised consistently across jurisdictions; and (4) which particular features of content, language, or format may pose difficulties for non-scientist report-users. We then suggest some ways to improve the readability of expert reports, based on findings that flagged particular issues.

Difficulty of Conclusions

In general, the conclusions written in case reports of forensic comparison of glass were *difficult* on average, and had a grade score of *university undergraduate* level. This finding mirrors the results of our previous study using the conclusions written as part of an international proficiency test of glass analysis (Howes et al., 2013). Although no jurisdiction's reports overall were at the *very difficult* level, none were in the range including *very easy, easy, fairly easy, or standard*. The level of difficulty of reports did not differ by intended audience. This suggests that despite some variation between reports by main intended audience, report style, and jurisdiction, in general terms, expert reports of forensic glass comparison were written at a level that would not be easy to read for a non-scientist audience. Rather, based on grade levels alone, the conclusions of reports were written at a level of difficulty that could best be described as appropriate for other scientists with similar specialised knowledge. It is worthwhile remembering that although many report-users undoubtedly possess tertiary qualifications, they are unlikely to be in science. Report-users who have postgraduate qualifications in disciplines other than forensic chemistry could not be expected to understand completely the conclusions despite that education. Whilst the results suggest that the use of long sentences may be a typical feature of the scientific language used in forensic chemistry, from a reader perspective, a blend of long and short sentences is more natural and reader friendly (American Psychological Association [APA], 2010). Past research revealed that teachers preferred psychologists' reports on students written at a Grade 8 level, to those written at more difficult levels (Pelco, Ward, Coleman, & Young, 2009).

The included measurement of lexical density added to this study by revealing that although levels of difficulty of reports (as measured by readability formulas) were similar across jurisdictions, lexical density differed, such that the conclusions of some jurisdictions were far less dense others. All conclusions were less dense than the abstracts of journal articles across a range of disciplines (Gholami et al., 2012). However, the conclusions of only a single jurisdiction were written at a lexical density associated with (non-scientific) written English (Halliday, 1993b). Past research has reported that readers prefer written material that is less lexically dense (Harrison & Bakker, 1998). This finding emphasises the importance of not relying solely on readability formulas to determine potential reading difficulty, but to consider the complexity of the sentences themselves. Lexical density per clause (rather than as a proportion of total text) was a more useful measure for the purpose of assessing complexity at the sentence level.

Reporting Uncertainty

The results confirmed that among forensic scientists who specialise in the comparison of glass in Australian jurisdictions, consensus has not been reached about how to communicate uncertainty. The most common approach across jurisdictions was to state support for a (source-level) proposition. However, other potentially necessary information such as the simple fact that propositions were considered, whether and which alternative propositions were considered, the inclusion of an evidence strength scale, the basis for the scale, and the reason for selection of a particular database were seldom provided. The use of the *could have* approach to suggest that two fragments could have come from the same source, without providing an indication of the significance of the evidence, was also in common usage. These issues represent departures from the principles of evidence interpretation as outlined by Evett et al. (2000). However, it was unclear whether the principles were followed and not reported. The present findings support the need for ongoing discussion, debate, and research.

Text Types of Expert Reports

The styles used within a jurisdiction were fairly uniform; differences across jurisdictions suggested the use of jurisdiction-specific laboratory in-house styles. The benefit of using a consistent style within a jurisdiction is that it can become a discourse norm. Discourse norms (Hagge, 1997) are textual features and conventions that are deemed appropriate by consensus of a particular discipline. The use of uniform formats allows scientists to address relevant questions within an organised structure (Wu, 2011) and allows readers to locate the information they seek (Burrough-Boenisch, 1999) because reader expectations are met and this decreases the cognitive load placed upon the reader (Meyer, Marsiske, & Willis, 1993). In psychological report-writing, report-users (teachers) preferred reports organised by themes rather than in a test-by-test format (Pelco et al., 2009). In expert reports, reports that organised results or conclusions by person rather than by item could be seen to provide this helpful structure, particularly when conclusions were also separated from results, and headings and subheadings were used.

The results of the analyses of content and sequence, language and format supported the classification of expert reports by main intended audience and by style. The expert reports across jurisdictions contained the same core sections in a similar sequence, and did reflect specific text types. Within the categories of reports by main audience (police and courts), different styles were evident. In reports for police, a brief form and a short form legal style document were used, which may be influenced by police and legal requirements. In reports for the courts, the scientific style was broadly based on the format of scientific journal articles (introduction, method, results, and discussion [IMRAD]). The legal style was broadly based on requirements of the form of expert reports outlined in a Practice Note on the form and content of expert reports (Keane, 2011).

The report categories identified can be seen as occurring along a continuum. In practice, their use is often not restricted to a single audience. For example, the reports intended for police of one jurisdiction, written in a prose or short form legal style, were reportedly often sufficient for courts. In another jurisdiction, the reports provided to police were the reports (scientific style) intended for court. Past research on writing psychological reports showed that writing a single report for use with multiple audiences contributed to the difficulties of writing readable reports (Harvey, 2006).

The selection of a particular style reflects beliefs and assumptions about how language works, or a language ideology (Eades, 2010). Reports intended for police were often much briefer than those for the courts. The purpose of these reports is to assist in operational decision making, and in this context, briefer reports may be appropriate. Furthermore, because police investigators have traditionally deferred to scientists on matters of scientific opinion (Roberts, 2002), it may not be surprising that the reports specifically to police investigators are brief. The question of whether a scientific or legal style is deemed more appropriate for addressing reader expectations for courts may depend upon the jurisdiction. It seems that the selection of a legal or scientific style for reports for court may reflect differences in perception at the jurisdictional level of how scientists can best assist the courts. The notion of language ideology of expert reports is discussed further below.

Particular Issues for Readability

It is important to acknowledge that the reports of each jurisdiction contained many aspects of content and sequence, language, and format that are appropriate and would be helpful to non-scientists report-users. However, potential readability issues for non-scientist report-users existed in each category of analysis of expert reports, as discussed below.

Content and sequence. It has been argued that some report-users may read only the conclusions (Rothwell, 2010) and that the expert opinion is the part of most interest to the courts (Allnut & Chaplow, 2000). The expert opinion should be clearly identified so that the reader is not confused about the demarcation between finding and inference (Curran et al., 2000; Allnut & Chaplow, 2000). In most reports, the opinion was clearly identified. However, in some reports, the finding and inference were presented in a single paragraph. This was not ideal as it could cause confusion for report-users.

In addition to identifying where expert opinion begins, the strength of reasoning is important. The facts, research, and expertise upon which the opinion is based should be clearly outlined for the reader (Allnut & Chaplow, 2000) to allow the reader to follow the logic of the scientist. Importantly, some notes about interpretation of the results were provided to the reader in almost every expert report.

Omission of the section on analytical techniques left a gap in logic between items and their results. Whilst brevity is encouraged in scientific writing, it may not be ideal to write the briefest possible report for police or for the courts. For instance, it may be that noting in reports that standard tests were (or could not be) used would flag potential issues to police investigators. More information may be preferable as it can enable a more complete understanding and be more useful to practitioners. For example, it has been shown that reports written about students by psychologists to inform teachers' classroom practice were preferred when they were specific and provided more detail (Mallin, Beimcik, & Hopfner, 2012).

Making assumptions about the background knowledge of the reader (e.g., that the reader already understands scientific processes such as analytical techniques) is unfounded for a non-scientist reader. Conversely, making assumptions that the information need not be understood (even at a general level) reflects a language ideology of deference to the expert. It may be expected that the readers defer to the scientists' knowledge to some extent. However, it seems that a distinction can be made between informed and uninformed deference. Although writing readable (psychological) reports has been found to be time-consuming (Harvey, 2006), writing in a way that can be understood by the audience communicates respect for that audience of other professionals working within the same system.

Language. In addition to the issues of sentence length and lexical density (discussed above under difficulty of conclusions), the language of expert reports of glass comparison was predominantly scientific language. We found that in expert reports, (as in psychological reports; Harvey, 2006) key specialist terms were often not defined. Even when defined, sufficient explanation or elaboration was not provided to assist the reader to understand the concepts. The issue of interrelated specialist terms (Halliday, 1993b) was evident. For example, if a GRIM 3 is used to measure an RI, a number of questions arise in the minds of non-scientist readers. What is a GRIM 3? And what is an RI? These questions lead to more questions. What can an RI tell us? What about what it cannot tell us? In other words, what are the limitations to this method (e.g., what happens if the glass has been heat damaged)? What else might we need to know (e.g., about different types of glass and different ranges of RIs) to understand the results?

This issue of interrelated specialist terms is not insurmountable. It indicates the need for elaboration and making links or inferences for the reader. The lack of elaboration and explicit links is consistent with writing for a specialist, rather than a non-specialist audience (Britton & Gülgöz, 1991). Providing explicit links refers to placing old information before new (Graves & Graves, 2003), or placing information from previous sentence in the topic position of the next sentence (Gopen & Swan, 1990) such that all necessary steps in logic are presented.[1]

Format. Most expert reports had a cramped format. Past research has found that cramped text is visually unappealing for readers because it can be perceived as overwhelming (Doak et al., 1996) or intimidating. The reasons for the cramped appearance were several. Margins had been narrowed beyond the default setting and also contained information in the remaining header and footer areas of the document. In most cases, the line spacing was single, and spaces between paragraphs and sections were predominantly single line spacing.

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[1] For a report relating to glass comparison, for example, instead of stating that “a GRIM 3 was used to measure RI”, a solution might be to explain as follows (where terms in bold indicate terms that were defined in a previous section of the report and in the glossary): “The GRIM 3 is an industry-standard instrument. It is used to compare tiny fragments of glass. It accurately and precisely measures the **refractive index** of clear or coloured glass. It can be used for glass from various sources, including windows from cars or houses, bottles, eye glasses, or drinking vessels.”

Headings were used most consistently in reports for court in the scientific style. However, some jurisdictions used all capital letters in headings. This capitalisation of headings is not recommended, because readers cannot see the “shapes” of words (the use of italics poses a similar problem), as the words become box-like (Doak et al., 1996). The use of consistent headings, despite differing case circumstances, allows report-users to skip ahead and back to the content they seek (Burrough-Boenisch, 1999).

The fonts used were Times New Roman and Arial. Times New Roman and similar fonts are best suited to reading hard copies of documents due to the serif (guiding the eye along the line; Doak et al., 1996. Arial and other sans-serif fonts may be best suited for documents read on-screen, although some may prefer Arial for documents due to its large appearance (Shrank et al., 2007). In fact, the main issue with fonts was their size. Particularly in reports for police, it was not uncommon to find that font size was made as small as 9-point to enable all information to fit on a single page. Font size in reports for court was often 11- rather than 12-point.

Implications and Suggestions for Writing Expert Reports

It may be possible to make several simple modifications to laboratory in-house style that enhance readability for non-scientist report users. Suggested modifications provided below are based on the issues identified and drawn from theory and research guiding observations. These may be viewed as supplementing the suggestions provided in our previous paper (Howes et al., 2013), which applied to the content and sequence, and language of conclusions specifically.

Content and sequence. Provide some form of reader orientation, whether a sentence outlining the purpose of the report, the nature of the case information received, a table of contents, or a brief summary. Include more – rather than less – information. For example, mention that standard analytical techniques were used and briefly explain them. If any variations were needed, explain why. Let readers know where and how to obtain further information about anything that is not clear to them as part of the report's meta-discourse (information in the report about the report).

Language. Define specialist terms when first used and explain their relationships with other terms. In addition to in-text definitions, provide a glossary of key terms if used on multiple occasions throughout the report. It is not always necessary to use long sentences. Where possible, break complex sentences into two or three shorter sentences. Do this by using overlapping propositions (i.e., restate old information from previous sentence in the new sentence to retain the flow in the reader's mind). If a sentence *must* be long, its readability may be enhanced by increasing the number of clauses, thereby decreasing the number of content words per clause. To do this, use the active, rather than passive, voice. Use a clear verb to show the action in each clause or sentence. Use adverbs, adjectives and prepositions, rather than using long strings of nouns.

Format. Consider how to show that terms have been defined in a previous section. For example, if a glossary is used, refer to it early in the text. Identify terms in bold (or with an underline) throughout the report to show that they have been defined in an earlier section of the report and can be found in an appended glossary.

Avoid using fonts smaller than 12-point Times New Roman. To enable readers to skip forward and back through the report to locate the information that they seek, use headings. Headings in bold font are effective as they are easily identifiable (but avoid headings of all uppercase or italicised letters). Provide headings for tables and within the columns of tables. Make headings concise and eliminate specialist terms from headings where possible.

Add white space by increasing margin size to at least the default setting of 2.54cm on all four sides. Increase line spacing to 1.5 or 2.0. For boxes, lists, and tables, opt for finer lines. Consider removing some gridlines (especially vertical gridlines) if it will not decrease clarity. If using tables to present results for multiple cases, then consider using separate tables for each case to decrease the complexity of individual tables. Consider that it may be possible to remove lines separating headers or footers from body text without any loss of clarity, and with gains in white space. If no word- or page-limit exists for expert reports, then the content need not be cramped or cluttered.

Limitations and Future Research

The current study explored the readability of expert reports of forensic comparison of glass. It is possible that these findings may generalise to some extent to reports of forensic glass comparison internationally, to aspects of reporting in which there is overlap between adversarial and inquisitorial systems, and possibly to reports of other sub-disciplines in forensic chemistry. Many of the recommendations to enhance readability could be applied to the reports of other disciplines in forensic science. To determine reporting differences by discipline, in our next study, we explore the readability of expert reports of DNA analysis.

In the current study, we focussed on the features of the texts. This necessarily entailed excluding from consideration certain constraints on scientists involved in writing the reports, and the non-scientists involved in reading and interpreting them (police investigators, lawyers, and judges). In practice, the writer and the reader are involved in making meaning from texts. In the next stage of research, we seek the perspectives of scientists to better understand the multiple influences on report writing. We seek the views of lawyers, judges, and police investigators to better understand the adequacy of expert reports for their purposes.

As this paper relates to the initial stages of our research, the modifications suggested herein were based on analyses of readability rather than usability. Past studies have demonstrated the validity of modifications informed by theory and past research to documents to enhance readability when tested with document-users (e.g., Feufel et al., 2010; Hirsh et al., 2009). Future research could evaluate usability of expert reports in their current form and when modified according to the suggestions we have provided.

Conclusion

The scientific language of expert reports poses a potential obstacle to their readability for non-scientist report-users. Our review of approaches to readability made a theoretical contribution, showing that the varied approaches each essentially examined features of content and sequence, language, or format. Using subcategories and items drawn from past theory and research, and from the reports themselves, we assessed holistically the readability of expert reports from all seven Australian jurisdictions that provide forensic comparison of glass. Reflecting the findings of our past research, in general, the reports were written at a level that would pose difficulties for non-scientist report-users. Issues with readability differed more by jurisdiction than by intended audience, and may reflect differing language ideologies within jurisdictions. This research provided a starting point from which to increase the readability of expert reports, without needing to alter the desirable features of current in-house laboratory styles. Increasing the readability of expert reports is intended to decrease the cognitive demands on report-users, and contribute to better comprehension of forensic science by non-scientist report-users. Ultimately, it is hoped that increasing readability of reports will enhance the efficiency and effectiveness of the criminal justice system.

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6

The Readability of Expert Reports for Non-Scientist Report-Users: Reports of DNA Analysis

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Abstract

DNA evidence can be extremely compelling. With ongoing scientific advances and applications of DNA evidence in the criminal justice system, it is increasingly important that police, lawyers, and judges recognise both the limitations of DNA evidence and the strength of the evidence in particular cases. Because most forensic science is formally communicated via expert reports, we analysed the readability of 68 such reports of DNA evidence from 6 of 8 Australian jurisdictions. We conducted content analyses using three categories: content and sequence, language, and format. Categories contained qualitative and quantitative items drawn from theory and past research. Report styles differed by jurisdiction and by main audience – police and the courts. Reports for police were brief and few links were made between sections in these reports. Reports for courts were less brief and used either legal or scientific styles. Common sections in reports for courts included: the scientist's specialised knowledge; laboratory accreditation information; item list; results; and notes on interpretation. Sections were often not in a logical sequence, due to the use of appendices. According to Flesch Reading Ease scores, reports for police had language that was *fairly difficult*, and reports for courts, *difficult*. Difficulty was compounded by the use of specialist terms. Reports for police and the appendices of reports for court often used very small font and single line spacing. Many reports for court contained tables that spanned several pages. Suggestions based on theory and past research are provided to assist scientists to enhance the readability of reports for non-scientists.

The Readability of Expert Reports for Non-Scientist Report-Users: Reports of DNA Analysis

Due to the research culture on which it is based, DNA evidence has been widely regarded as the gold standard in forensic science (Shelton, 2010). This has been especially true since the release of the 2009 report of the (US) National Academy of Sciences on strengthening forensic science (Edmond, 2011; National Academy of Sciences [NAS], 2009). DNA evidence has provided a model for other forensic sciences to emulate – a model of forensic science with a research base (Murphy, 2010). DNA evidence has permitted numerous previously unsolved crimes to be solved (Jobling & Gill, 2004; Murphy, 2010), and hundreds of wrongful convictions in the US to be overturned (Garrett, 2008; Garrett & Neufeld, 2009). To date in the US, there have been 311 post-conviction DNA exonerations, with 152 new suspects located in those cases (Innocence Project, 2013). At the same time, ongoing advances in science and technology have made DNA increasingly complex (Murphy, 2010). Ethical issues have arisen with regards to the collection and storage of DNA evidence (Aarli, 2012), the use of familial DNA typing (Ram, 2011), and the use of DNA to infer features of the appearance (particularly the race) of a suspect (M’Charek, 2008).

Past studies have demonstrated the importance of DNA evidence to jurors in reaching a guilty verdict (Wheate, 2010). The presence of DNA evidence led to increased conviction rates by mock jurors and jury-eligible people (Goodman-Delahunty & Hewson, 2010; Lieberman, Carrell, Miethe, & Krauss, 2008). Furthermore, DNA evidence tended to be over-valued by mock jurors when case context was known, suggesting that more guilty verdicts may be reached than the evidence could logically support (Smith, Bull, & Holliday, 2011). This has led to discussion and debate about how best to indicate the strength of forensic evidence in general, and DNA evidence in particular (e.g., frequencies, random match probabilities, likelihood ratios, or verbal equivalents to the likelihood ratios), so that its significance in a given case is most accurately communicated in the court room (Aitken, 2009, 2012; Kahn, 2009; Ligertwood & Edmond, 2012; Lindsey, Hertwig, & Gigerenzer, 2003; Lynch & McNally, 2003; Martire, Kemp, & Newell, 2013; Martire, Kemp, Watkins, Sayle, & Newell, 2013).

But the fact that DNA evidence can be compelling in a case is a perception not limited to jurors. Failure to consider the limitations of DNA evidence, and failure to consider other evidence alongside DNA evidence could be (Gans & Urbas, 2002) – and has been – implicated in more recent wrongful convictions (Vincent, 2010). In an Australian case (the Jama case) a wrongful conviction was made on the basis of a contaminated sample of DNA evidence alone. Justice Vincent’s inquiry into the case affirmed the importance of ensuring that police, lawyers, and members of the judiciary understand the limitations inherent in any evidence that informs their decision-making in the criminal justice system (Vincent, 2010).

Police, lawyers, and judges are not expected to understand DNA in the same way that forensic biologists would – after all, accessing case-relevant specialised knowledge is the purpose of engaging experts (Freckelton & Selby, 2009). However, recent studies confirmed that the level of understanding of DNA evidence by police, lawyers, and judges may be insufficient. Even in recent times, a US study revealed that the use of DNA evidence in cases of unsolved serious crimes was extremely limited in some jurisdictions (Schroeder & White, 2009). The underutilised potential of DNA evidence was attributed not only to laboratory backlogs of unanalysed DNA samples, but also to gaps in the knowledge of police investigators of the potential of DNA as an investigative tool (Schroeder & White, 2009; Strom & Hickman, 2010).

Like police officers, lawyers and judges may increasingly encounter DNA evidence in their cases, but it does not follow that increased familiarity equates to understanding (Cashman & Henning, 2012; Findlay & Grix, 2003). Research has shown that lawyers may find it difficult to generalise knowledge about DNA evidence from one case to another, due to the specificity of issues relating to evidence in each case (Cashman & Henning, 2012). It has been argued that reliance on DNA evidence in the absence of any other evidence represents a failing in procedural justice, setting a dangerous precedent for future unsafe verdicts (Gans, 2011). Yet, at times, judges have permitted cases to be heard based on DNA evidence alone (Gans, 2011; Vincent, 2010), upholding the conviction on appeal in one such case (Gans, 2011).

Recently, the effectiveness of DNA evidence has been demonstrated in solving serial property crimes (Roman, Reid, Chalfin, & Knight, 2009; Wilson, McClure, & Weisburd, 2010; but see also Briody & Prenzler, 2005). It seems likely that the use of DNA evidence will continue to expand as the collection and analysis of evidence become more time- and cost-efficient. Research has indicated that less over-valuing of DNA evidence (among jury-eligible people) was associated with greater understanding of DNA evidence and more education in mathematics and science (Goodman-Delahunty & Hewson, 2010; Hans, Kaye, Dann, Farley, & Albertson, 2011). But it cannot be assumed that police, lawyers, and judges have education in maths and science beyond the level associated with compulsory schooling (Grade 10 or age 15-16 years), because these disciplines are not prerequisites to careers in law or policing (Howes, Kirkbride, Kelty, Julian, & Kemp, 2013). Generally, past research has suggested a need for ongoing education about DNA for police, lawyers, and judges (Findlay & Grix, 2003; Roman et al., 2009; Vincent, 2010) and increased multi-disciplinary awareness between all who report and use DNA evidence (Kelty, Julian, & Ross, 2013; Walsh, 2005).

Indeed, to facilitate effective and efficient functioning of the criminal justice system with regards to expert evidence, a number of philosophical and practical changes are currently underway. For instance, a growing trend exists both in Australia and in Europe to cooperate across jurisdictions in the provision of forensic database information (Hufnagel, 2011). Partial mirror legislation now exists in Australian jurisdictions to facilitate the exchange (Hufnagel, 2011). Australian courts are moving towards more similar approaches to expert evidence, with several jurisdictions adopting uniform evidence laws (Australian Law Reform Commission, 2005; Odgers, 2012). At the same time, a set of four new Australian standards for forensic science, based on internationally accepted best practice, has been developed and published. The fourth of these standards is for reporting (Australia New Zealand Policing Advisory Agency – National Institute of Forensic Science, 2013). Given this context, it is timely to consider current reporting practices and potential future directions.

Current Study

In both the adversarial (e.g., Australia, Canada, New Zealand, United Kingdom, and United States of America) and inquisitorial legal systems (e.g., countries of the European Union), expert evidence is most commonly provided in the form of expert reports (Broeders, 2003; Rothwell, 2010). The need to make DNA profiling results and expert interpretations comprehensible for non-scientists in court room contexts was recognised early in the use of DNA in trials, with suggestions to standardise the format of its presentation (Atchison & Cordner, 1989; Magnusson, 1993; Magnusson & Selinger, 1990). However, very few studies have explored the readability (ease of understanding due to the style of writing (Klare, 1963) of the expert reports for the police, lawyers, and judges who increasingly encounter such reports in their work.

Our current programme of research draws from the theoretical framework of systemic functional linguistics to address this issue. Under this framework, language is characterised as a resource for making meaning (Halliday & Martin, 1993). Understanding the language of science is synonymous with understanding the science itself (Halliday, 1993a). But the language of science is a specialised language (Halliday, 1993b) and contains features that make it difficult for non-scientists to understand (Fang, 2005; Halliday, 1993b). In articulating the theoretical framework of systemic functional linguistics, Halliday and Martin (1993) argued that a broad perspective is appropriate for gaining a holistic understanding of a text. In our previous work, we found that past approaches to readability assessment from differing theoretical perspectives consistently identified aspects of texts under one or more of the following three categories: content and sequence, language, and format (Howes, Kirkbride, Kelty, Julian, & Kemp, 2014).

One method suitable for analysing trends in written communication is content analysis (Babbie, 2010; Krippendorff, 2004). To assess the readability of DNA reports, we conducted a content analysis focusing on content and sequence, language, and format, using items drawn from past research. We previously reported on the readability of conclusions of proficiency tests of forensic glass analysis, (considering content and sequence; and language) (Howes et al., 2013); and the readability of reports of forensic comparison of glass (considering all three categories; Howes, Kirkbride, Kelty, Julian, & Kemp, 2014). This paper reports our study of the readability of reports of DNA analyses from six of Australia’s eight police jurisdictions. Current reporting practices and the readability associated with them are explored. We provide suggestions based on theory and past research to assist scientists in writing reports that are more readable for the non-scientists who use them.

Method

Sampling Procedure

Letters introducing the research and information sheets were sent via email to the laboratory directors of forensic laboratories in all eight Australian jurisdictions (six state, one territory, and one federal police force (Australian Bureau of Statistics [ABS], 2012). Laboratories providing forensic DNA analysis in Australia are located under police, health, or attorney-general's departments. Participating laboratories were asked to send (electronically) 10-15 recently written, de-identified reports of DNA analysis from different case types to show the range of their reporting styles. The rationale for requesting 10-15 reports from each participating jurisdiction was to cover the range of reporting styles for jurisdictions and to ensure that features anomalous to a particular report would not be coded as general features of the report type.

Sample

Expert reports of DNA analysis were received from six of the eight laboratories that had been invited to provide examples of the reports. To maintain anonymity, participating jurisdictions were labelled from A to F in no particular order. Seventy-three reports were received, consisting of between 10 and 16 reports from each participating laboratory. Of these, 58 were final reports for the courts; 10 were interim reports for investigators; and 5 were printouts of case summaries recorded in an electronic database accessible by police investigators. The 5 printouts referring investigators to reports were excluded from analysis, as they were not reports. The resulting sample consisted of 68 DNA expert reports. The unit of analysis was the report by main intended audience (police and the courts) for each jurisdiction.

Materials

As is appropriate under the theoretical framework of systemic functional linguistics, we used an expansive list of items drawn together from past approaches to content analysis (Howes et al., 2014). The categories and items shown in Table 1 were used to conduct a content analysis of the DNA reports.

As shown in Table 1, in addition to qualitative analyses, quantitative measures of readability were included under the categories of language and format. Under *language*, for the conclusions of reports, we considered the readability statistics obtained from Microsoft Word 2010. In Microsoft Word, readability statistics for a document can be obtained by selecting the Review tab of Microsoft Word, and checking the box in the Spelling and Grammar pane that says “show readability statistics”. The readability statistics provided include the numbers of sentences per paragraph; words per sentence; and sentences in the passive voice. Also included are the Flesch-Kincaid (FK) grade level (approximate number of years of US education required to read a particular text); and Flesch Reading Ease scores. The Flesch-Kincaid grade level is given by the formula: FK = 0.39 (total words/total sentences) + 11.8 (total syllables/total words) – 15.59 (Kincaid, Fishburne, Rogers, & Chissom, 1975). The Flesch Reading Ease score is given by the formula: FRE = 206.835 – 1.015 (total words/total sentences) – 84.6 (total syllables/total words; Flesch, 1948).

Table 1

Categories, Subcategories, and Items Coded and Described in the Assessment of Readability of Expert Reports

Guide for observations		
Category	Subcategories	Items coded for presence and/or described
Content and sequence	Reader orientation	Summary, purpose of report/examinations, nature of case, case context
	Meta-discourse	Case reference numbers, information about use of the report, contact details, accreditation details, signatures, dates, relevant legal acts, relevant scientific protocols
	Main concepts and sequence	Specialised knowledge of scientist, item list, item custody (and dispatch) information, methods of analysis/analytical techniques, results, notes on interpretation/discussion, conclusion/s, references, glossary, other appendix
	Coherence (links and flow)	Links or logical flow between sections, old information before new (can also be observed at sentence level with proposition overlap)
	Dependence of text on appendix	Glossary, other appendix, appendix mentioned in body of report
	Elaboration of important content	References, limitations of techniques used, background information provided, case relevant information, database information, notes on interpretation, separate results and conclusions
Language	Tone of writing	Formality, passive or active voice, use of first person, different tone in different parts of report
	Technicality of vocabulary	In-text definitions, glossary provided, abbreviations or acronyms expanded
	*Readability statistics	Number of sentences per paragraph, number of words per sentence, proportion of sentences in passive voice; Flesch-Kincaid grade level; Flesch Reading Ease
	*Lexical density	Number of content words per clause; number of content words as a proportion of total words
	Communicating uncertainty	Use of expected population frequency, random match probability, likelihood ratio, verbal equivalent of likelihood ratio
Format	Length of reports	Number of pages
	Information chunking	Use of paragraphs (numbered, indented, number of sentences per paragraph) Use of headings and subheadings (concise headings in lay terms, consistent headings used)
	Fonts	Consistent use of fonts, footed font used, at least 12 point font, use of bold for headings and subheadings (not all upper case letters or italics)
	White space	Line spacing, margin size, headers and footers, visible gridlines in lists and tables
	*PMose/IKirsch document readability	Structure and density of lists and tables

Note. The categories and items were derived from theory and past research about readability (see Howes et al., 2014), from documents informing the contents of expert reports, and from items observed in the expert reports.

Under *format*, we considered the complexity of lists and tables using the PMose/IKirsch document readability formula (Mosenthal & Kirsch, 1998). For each list and table, scores were assigned for structure (1 = single column list with heading; 2 = table/list with multiple columns with headings; 3 = table with column and row headings; 4 = table with row and column headings and subheadings). Scores were assigned for three aspects of table density. First, for 15 or fewer table headings, a score of 1 was assigned (16-25 headings = 2; 26-35 headings = 3; 36-46 headings = 4; greater than or equal to 47 headings = 5). Second, for items (each subheading and each cell in the body of the table; but note that for cells containing text, each clause counts as one item) scores were assigned such that 75 or fewer items scored 1 (76-125 = 2; 126-175 = 3; 176-225 = 4; 226 or greater = 5). Third, a point was added for each reference within the table to table notes or to other documents. Scores for table structure and density were summed. Total scores correspond to grade levels associated with adult proficiency in reading (Mosenthal & Kirsch, 1998) as shown in Table 2.

Table 2

Interpretation of Document Scores as Complexity Levels and Grade Equivalents

Document Complexity Level	Total Document Score	Grade Equivalents (in terms of NAEP reading scale)[a]
1	3-5	Grades 4-8
2	6-8	Grades 8-12
3	9-11	Grade 12 to some post-secondary education
4	12-14	Some university to undergraduate degree
5	15-17	Undergraduate degree to postgraduate degree

Note. For example, Table 2 has a combined list structure (score 2), with three headings or labels (score 1), and 15 items (score 1), and two dependencies or table notes (score 2). These scores total 6 – giving a document complexity score of 2, and a grade level of 8-12.
[a](Mosenthal & Kirsch, 1998).

Procedure

Data preparation. Prior to obtaining readability statistics, the conclusions of each report were identified and pasted into a table in a Word Document. When conclusions were presented in tables, the cells containing conclusions were selected, with each cell of the conclusion in the original report considered a separate paragraph for the purposes of analysis (unless line spaces had been used within the cell to create additional paragraphs). Cells that did not contain full stops were treated as single sentences. When multiple conclusions were presented in a single report using the same (or extremely similar) wording, one conclusion was used as a sub-sample because adding more examples of the same paragraphs did not alter the readability statistics. Conclusion cells that were left blank or stated “not applicable” were not included as they were not considered to be examples of conclusions.

The conclusions were then prepared for analysis following the data preparation procedure we had used in previous work (Howes et al., 2014). Paragraph numbers and sub-headings contained within the conclusions, where present, were deleted. Long strings of numbers used in the text of conclusions (e.g., item numbers, or case numbers) were replaced with single-digit numbers to ensure that the readability scores obtained would reflect the use of words rather than numbers. (The use of numbers can inflate readability scores.) In the de-identification process, most laboratories had replaced identifiable information such as names, and addresses with filler items. Where an item of text had been deleted for the purpose of de-identification and not replaced, we replaced it with a filler item similar to those used by the laboratories (e.g., surname removed – “the suspect” or “Suspect A and Suspect B” were added as appropriate). This retained the flow of sentences and more accurately reconstructed the word counts.

Qualitative data analysis. Reports were printed and read prior to content analysis of readability. During this preliminary stage, notes were made about the textual features of reports from each jurisdiction. Reports were re-read multiple times to code for each concept assessed under the categories of content and sequence, language, and format. For each report, codes on each conceptual item were recorded. Codes were compared first within and then between jurisdictions. Descriptions were recorded alongside each concept for each jurisdiction, and formed part of the data corpus.

Results

The categorisation of reports is shown in Figure 1. The use of these categories was supported by a preliminary content analysis of the concepts contained in the report and their organisational structure.

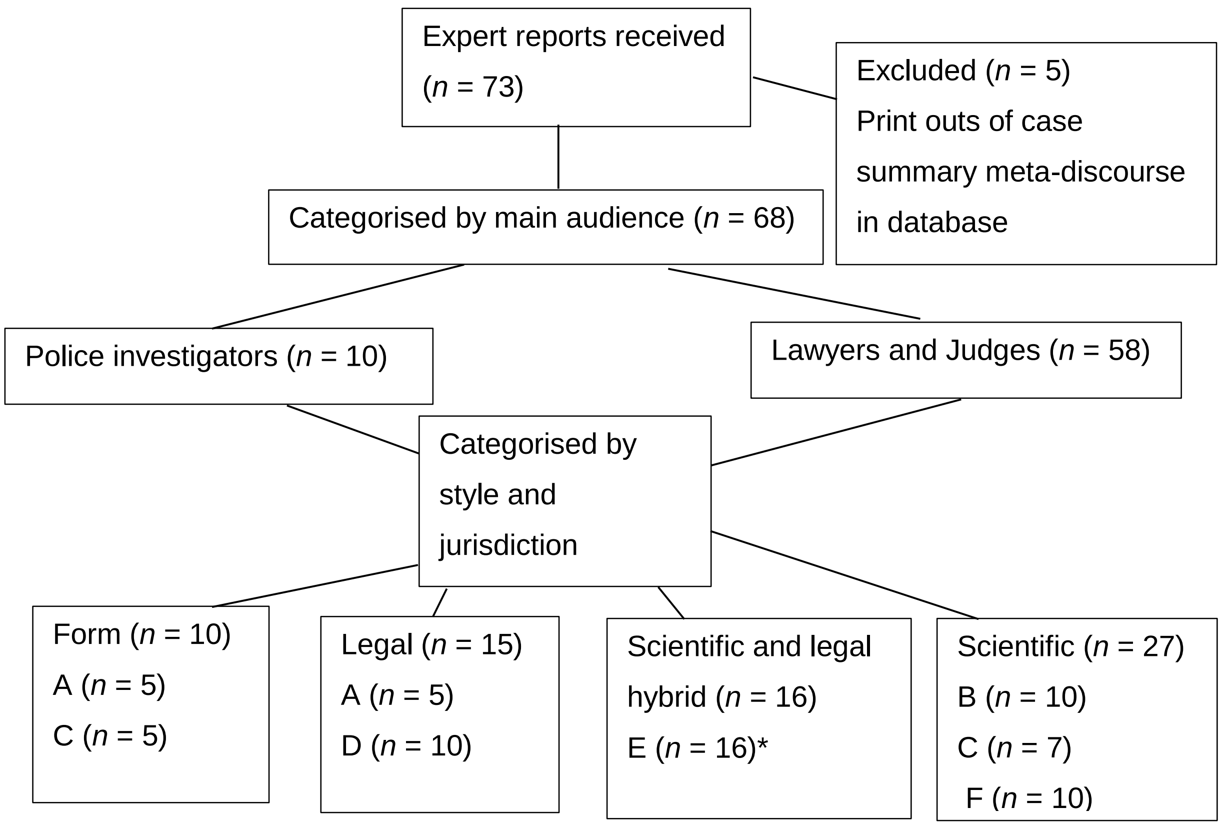

Figure 1. Preliminary analysis: Categorisation of expert reports by main audience, style, and jurisdiction

* Discussed in Results with reports for court of scientific style, due to the presence of an attached statement outlining the scientist's specialised knowledge.

Table 3

Main Features of Expert Reports by Report Type, Jurisdiction, and Style

Section	Present in reports		Explanatory notes on the nature of information included in reports
	For police	For courts	
Nature of case	A, C	C, D	For police: case reference number only (C) For court: case reference number only (A, F). Case numbers and suspects involved (D, E)
Instructions for document use, advice on where to obtain further information	A, C	A, B, C, D, F	For police: not to be used in court; a statement can be prepared (A, C) For court: offered full chain of custody information (C); terms in italics are in glossary (F); more detailed report can be issued (F); not to be reprinted except in full (A, B, D, E, F).
Specialised knowledge		A, B, C, D, E	For court: in body of report (legal style; A, D). As statement attached to front of report (scientific style; C, E); as statement attached to back of report (scientific style; B)
NATA accreditation		A, B, C, D, E, F	Number and symbol included
Item list	C	A, B, C, D, E, F	In a table (C). In results table only (B, F). Item as subheading to further information about preliminary analysis and results or as bulleted list (E) and (in addition) as a bulleted list in evidentiary certificate attached (E).
Item custody details		A, C, D, E	In item list table (C). In evidentiary certificate attached (E).
Mention of methods of analysis		A, (B, C, D), F,	Very brief (A, F) In appendix (B, C, D, E)
Results	A, C	A, B, C, D, F	In tables (sometimes A; B, C, D, F). In text (E; DNA profile table attached in evidentiary certificate).
Statistical interpretation		A, B, C, F	Propositions provided prior to results (C, E); propositions provided in results table (sometimes B); likelihood ratio in results table (B, C) sometimes (D). Probability estimate in results table (F). Random match probability (E). Expected occurrence in general population (D). Likelihood ratio for mixed profile only (A, D, E) database used is mentioned (A, E).
Conclusion		C	In results table by item (C)
Glossary of terms		B, F	Glossary attached as an appendix.
Notes on interpretation		B, C, F	In appendix (B, C, E). As notes to table (F). In body of report (E) when DNA not obtained from items sampled.

Content and sequence

Main concepts and sequence. The main content and sequence of reports for police and for the courts is outlined in Table 3. Reports for police differed between the two jurisdictions that submitted them. The reports for police of Jurisdiction A were briefer than those of Jurisdiction C. Both jurisdictions provided case reference numbers and briefly stated the nature of the case. Jurisdiction C provided a list of items with descriptions while Jurisdiction A did not. Both provided brief results. In the results, Jurisdiction A referred to items by description; whereas Jurisdiction C referred to the items tested by number. Both jurisdictions provided the signature of the reporting scientist.

Reports for court differed both by jurisdiction (six jurisdictions provided reports for court) and by style. Reports for court in legal style (Jurisdictions A & D) began with the name, and specialised knowledge (occupation, qualifications and experience) of the reporting scientist. Jurisdiction D’s reports included a statement that the scientist had read the relevant legal codes, while Jurisdiction A’s reports explained that the report was based upon information known at the time of the examinations, and that if further information were to become available, it may necessitate further examination. Items (exhibits) were listed with dates received (and other item custody information, such as where they had been stored or from whom they had been received). Results were usually provided item by item. Jurisdiction A occasionally provided results by person (e.g., victim and suspect). Jurisdiction D included a note that other scientific staff may have assisted in the testing, and that further information (about processes) was located in the appendix. Both concluded with signatures and dates; one jurisdiction’s reports had space for the signature of a witness.

Reports for court in scientific style from three of the four jurisdictions that used this style contained statements that were either attached at the front (as the first page or following the title page) or the back of the scientific reports. These statements contained details of the scientist's specialised knowledge and experience, legal rules or codes that had been read, the fact that further examination may be required if more evidence were to come to light, the number of pages attached or in total, a statement as to the truth of the report, and signatures of the scientist and a witness.

Reports for court in scientific style typically had title pages indicating the case numbers and nature of the case, and item lists with received dates and descriptions. Tables were typically used to present the results and interpretations. Explanations of methods of analysis and interpretation were often provided in appendices.

Links or flow. In reports for police, due to the brevity of reports, few links between sections were evident. In reports for court in scientific style, the flow between sections was somewhat limited by the placement of methods of analysis in an appendix, the need to search for terms in glossaries, or the disjointedness inherent in having multiple attachments to the report. It was not always clear which document was considered to be the main report and which were attachments.

Reader orientation. In reports for police, the nature of the case was presented at the top of the form in case numbers and/or brief descriptive terms depending upon the jurisdiction. In reports for court, in legal style, the nature of the case was presented as case numbers or brief description (depending on the jurisdiction) under the main heading. In reports in scientific style, the nature of the case was typically reported on the title page. None of the reports had summaries of case information or findings. The reports of one jurisdiction contained details of the requests for examination of items.

Meta-discourse. Reports for police contained meta-discourse at the top of the front page, and in the footer. At the top of the page were case numbers and the nature of the relevant incident. For one jurisdiction, the police officer and station was also reported, in the other the logo of the relevant police force was included. In the footers for both jurisdictions, the date (of printing, or of review or issue), and page number were located. In addition, reports for police explicitly stated that the report was not to be used in court. In one jurisdiction, this was stated twice.

Notable differences emerged between meta-discourse of reports for court and reports for police. Reports for the courts contained the contact details of the laboratory, usually at the top of the first page. Often reports for court contained logos of the relevant organisations (police forces, health, and attorney-general’s departments) within which the laboratories were located. Details of accreditation with the National Association of Testing Authority (NATA), the accreditation number, and the NATA logo were prominent on the first page (or title page) of reports. With the NATA information was a statement that the document was not to be reproduced except in full (although the reports of one jurisdiction did not state this). Only the reports of one jurisdiction provided substantial information on how to use the report, including how to identify terms listed in the glossary, where to obtain further information, and the nature of further information available.

Dependence of text on appendix. Reports for court were typically presented with a number of attachments. Scientific style reports from three of four jurisdictions had a statement attached to outline scientific qualifications and experience. Both legal and scientific style reports had glossaries attached (2 jurisdictions), or explanations of laboratory procedures, methods of analysis and interpretation, and quality control (4 jurisdictions). The reports of Jurisdiction B included a copy of the form requesting examination that scientists had received from police. The reports of Jurisdiction E had both a statement and an evidentiary certificate attached. This seemed unusual because the evidentiary certificate repeated the information of the scientific report in a legal style, with the addition of item custody information. Only a single jurisdiction (A) presented the reports for court (legal style) as a stand-alone document without attachments. Only one of the two jurisdictions that used a glossary of terms (F) contained meta-discourse referring readers to the glossary and explaining that terms indicated in italics had explanations in the glossary. Appendices used to explain methods of analysis were generally referred to in the body of reports, but in the reports of Jurisdiction D, the appendix was referred to after results were presented.

Elaboration of important content. The methods used to determine whether bodily fluids were present on the items received were often not explained, or explained in an appendix. The fact that samples were taken from items for the purpose of testing was often not explained, or explained in an appendix. The methods used to select samples from items for the purpose of DNA testing were often not described or explained in the body of the report, except in the reports of one jurisdiction.

In reports for police, there was little elaboration of information about results. Meanings of the results often appeared not to be explained. A lack of explanation or elaboration about inferences was also evident in many reports for court. In cases where multiple samples from multiple items had been tested, each item had its own result and conclusion. Usually these conclusions were not synthesised to give an overall indication of whether a DNA profile or profiles had or had not been obtained from a particular item. When multiple items belonging to a particular suspect were tested, overall conclusions about the DNA located or not located on the belongings of that suspect were not made.

Language

Tone of writing. For the most part, the reports were written in an objective and scientific style. This was achieved through extremely limited use of the first person (“I”). Use of the first person was more common in reports in legal style and statements attached to scientific style reports (because they outlined specialised knowledge of the scientist).

Reports for police (and sometimes for courts) at times took a more personal tone when suggesting that the reader make contact for further information. The gravity of reports was communicated through official wording and imperative forms (e.g., “This form must not be used in court”; “This document shall not be reproduced, except in full.”).

Technicality of vocabulary. The reports seemed to assume knowledge of technical terms (and general terms used with specialist meanings) such as *cellular material, excluded, partial profile, mixed profile, major component, minor component, sample x of item y,* and *Y-STR*. These types of terms were not defined in the body of reports, and not always clarified in an appendix. Because the idea of taking samples from items to test was not explained, the terms or numbers used to indicate samples of items (e.g., “01A – tapelift”; “21-7 – wet swab”) may not be understood by all report-users.

When appendices were attached to reports, whether to explain terms or methods of analysis, the language in them was often scientific. For a reader seeking clarification of one term (e.g., *amylase positive*), it was likely that the explanation contained other terms that would require clarification (e.g., *presumptive test*). Not all necessary terms were explained in the glossaries, and terms not used in the report were also contained within glossaries.

Readability statistics. Table 4 shows readability statistics by main audience and report style. Conclusions commonly consisted of paragraphs containing 1-2 sentences each. The average number of words per sentence ranged from fewer than 6 words per sentence to more than 29 words per sentence. According to the Flesch Reading Ease and Flesch-Kincaid grade level scores, interim reports for police investigators were written at a level of *fairly difficult* (requiring reading ability at a Grade 10-12 level). The reports for the courts were written at a level of *difficult* (requiring reading ability from high school to university undergraduate levels), with reports of one jurisdiction *very difficult* (requiring reading ability at a university postgraduate level).

Readability statistics were also obtained for the appendices. Use of the passive voice ranged from 31-49%. The Flesch Reading Ease scores of appendices were in the range of *difficult* (FRE = 31.0-42.3), although one jurisdiction had a *very difficult* (FRE = 26.4) appendix. The Flesch-Kincaid grade level associated with most appendices was a level requiring *university undergraduate* (FK = 13.2-14.4) reading ability, although the appendix of one jurisdiction required reading ability associated with *senior high school* (FK = 11.3).

Lexical density. Content words as a proportion of total words in conclusions of DNA reports ranged from 50-64% in reports for police, and 52-81% in reports for courts (see Table 5). In two jurisdictions, the conclusions of reports were written in note form rather than in complete sentences. Conclusions in note form did not always contain verbs (e.g., “Mixed DNA profile – three contributors including victim.” as opposed to “A mixed DNA profile *was obtained*, consisting of DNA from at least three contributors, including the victim”) and therefore did not consist of clauses. Note form made each point brief (consisting of as few as three words), but increased content words as a proportion of total words (i.e., there were few prepositions, conjunctions, auxiliary verbs, and pronouns). High scores on lexical density, when measured as a proportion of total words, were associated with writing that was in note form as opposed to sentence form.

For the reports of the four jurisdictions with conclusions written in sentence format, lexical density, measured as content words per clause, ranged from 5.6-9.4. These scores corresponded to a level of lexical density associated with standard written English, or slightly above. Lexical density, as measured by content words per clause, was not calculated for conclusions written in note form because they did not consist of clauses.

Table 4

Mean Readability Statistics of Expert Reports of DNA Analysis by Main Audience, Report Style, and Jurisdiction

Report Characteristics			Mean Scores						
Main Audience and Report Style	Jurisdiction	Based on *n* reports	Sentences per paragraph	Words per sentence	Proportion of passive voice	Flesch Reading Ease		Flesch-Kincaid Grade Level	
Police									
Form	A	5	2.10	20.92	34.60	51.66	Fairly Difficult	11.22	Senior High
	C	5	1.66	13.84	89.20	50.64	Fairly Difficult	9.58	High School
Court									
Legal	A	5	2.30	22.88	32.80	44.08	Difficult	12.64	Undergraduate
	D	10	2.05	14.18	9.30	49.65	Difficult	9.8	High School
	F	10	1.92	9.58	15.40	44.93	Difficult	9.33	High School
Both	E	16	1.19	17.33	60.25	42.73	Difficult	11.56	Senior High
Scientific	B	10	2.81	5.59	0.80	45.48	Difficult	8.26	High School
	C	7	1.00	29.57	0	19.91	Very Difficult	17.76	Postgraduate
Unweighted Total		68	1.88	16.74	30.30	43.64	Difficult	11.27	Senior High

Note. Because the purpose of these scores is to provide heuristics of readability, further statistical comparisons were not undertaken.

Table 5

Mean Lexical Density, Density and Complexity of Matrices, and Length of Expert Reports of DNA Analysis by Main Audience, Report Style, and Jurisdiction

			Report Characteristics			
			Mean Scores			
			Lexical density of conclusions			
Report Audience and Style	Jurisdiction	Number of reports	Lexical words per clause	Lexical words as % of total	Length of report (pages)	Grade level of matrices[a]
Police						
Form	A	5	9.4	54	1	NA[b]
	C	5	7.1	60	2.2	4-7
Court						
Legal	A	5	7.6	60	5.2	4-7 in text or table
	D	10	6.8	52	7.4	4-7 and 8-12
	F	10	-	76	4.4	12 – post secondary education
Both	E	16	8.0	58	13	4-7 in text item list; 4-7 results table
Scientific	B	10	-	81	10.8	4-7, 8-12 and 12-post secondary
	C	7	5.6	54	16	4-7 and 8-12

[a]"in text" indicates that the table contained no gridlines. Lists of items presented in text either formed part of a paragraph as bulleted or numbered points. [b]"NA" indicates that no separate list of items was provided and results were presented in paragraphs rather than in a table.

Communicating uncertainty. In the reports for police of one jurisdiction, correspondence between DNA profiles obtained from suspects' reference samples and from items from crime scenes were reported as matches (e.g., "…matched the components attributed to Suspect ID [confirmed as authorisation number…]"). In the other jurisdiction, matches were reported as non-exclusions (e.g., "Suspect cannot be excluded."; "Suspect is not excluded.").

In the reports for court (legal style), scientists sometimes reported that the DNA recovered “had the same profile as (name or identifier of Suspect)” or “matched the DNA profile attributed to Suspect”. One jurisdiction also reported the expected occurrence of the DNA profile in the general population (e.g., “this profile is expected to occur in approximately 1 in *n* individuals in the general population” and referred to the population databases used to calculate the figures. When mixtures of DNA were identified, the reports of both jurisdictions provided (or offered to provide upon request) the likelihood ratios (or statistics) calculated. One jurisdiction provided the (source level) hypotheses that had been considered (prosecution and defence hypotheses) along with the assumption that two people had contributed to the profile.

One jurisdiction’s reports (scientific style) sometimes reported that a sample “matched [an individual’s] reference DNA profile” as did reports in legal style. The relevant DNA profiles were provided in a table. Sometimes in reports of single source matches from the same jurisdiction, probability estimates were included. For mixed profiles, the assumption of two contributors to the profile was stated prior to presenting two competing (source level) hypotheses. The conclusion then stated the likelihood of one hypothesis in comparison to the other.

Another jurisdiction reported “match” or “not excluded” and included probability estimates for DNA profiles. For a profile of a single individual the chance of a second unrelated person found to have the same profile as that of the evidence sample was calculated. For mixed profiles, the chance of a randomly chosen person having a profile that would not exclude that person as a contributor to the DNA profile from the evidence sample was provided.

Two jurisdictions’ reports (scientific style) consistently included the (source level) propositions (C) or hypotheses (B) considered. One jurisdiction provided a likelihood ratio and specified the hypothesis that the results favoured (e.g., "17 billion in favour of H1"). The other jurisdiction provided a likelihood ratio and a conclusion specifically stating that the results provided support (using a verbal conclusion scale) for a particular proposition (e.g., "this finding…provides extremely strong support for the proposition that…").

Format

Length of reports. The page lengths of reports are shown in Table 5. Although the interim reports for police investigators were substantially shorter than the reports for courts, the reports for court contained a number of pages that were supplementary to the report itself. In some cases, the main part of the report consisted of fewer pages than did the attachments.

Information chunking. In reports for police and for court, paragraphs were not indented, but were separated by an extra line space. The reports for court of one jurisdiction used numbered paragraphs. The paragraphs of statements attached to the front of reports in one jurisdiction were numbered.

The results and interpretations of most reports for court were presented in tables. Often, a single table was used to present results from a number of different items, and even for items that related to different cases. This meant that a single table could span a number of pages. In one respect, this meant that all results were grouped under a single column heading.

Headings. In reports for police, a heading was used for "results" or for "results and comments" but subheadings appeared to be used only when large numbers of items were examined for a single case. In these cases, the item descriptions or item numbers and descriptions were used as subheadings. At times, additional case numbers preceded item numbers, when items from multiple cases were reported together.

In reports for court (legal style) of one jurisdiction used items as headings (under which results and interpretations were presented). The other jurisdiction used tables to present findings, and therefore used headings at the top of the table. It is worth noting that although the tables sometimes spanned a number of pages, the headings were not repeated at the top of pages on which the table continued.

In reports for court (scientific style) headings were used in reports whether or not tables were used to present results. In reports for court (scientific style), headings were repeated at the tops of pages on which tables presenting results continued.

White space. Line spacing in reports for police was generally single (1.0) line spacing. Although the reports for court in legal style usually had 1.5 line spacing, the reports for court in scientific style usually had 1.0 line spacing. Of the reports in scientific style, the attached statements of one jurisdiction sometimes had line spacing of 1.0, but otherwise 1.5 or 2.0. The line spacing in appendices was often single line spacing, even if body text was more spread out as in reports for court in legal style. When single line spacing was used, usually an extra line was left between paragraphs. However, extra lines tended not to be left in appendices, despite the use of single line spacing.

Margins appeared to be at the default settings of Microsoft Word (2.54 cm) in the reports of two jurisdictions. In other jurisdictions, the margins were narrow on the right hand side. Most reports contained text and/or symbols or signatures in the footers, and some also contained text in the headers, further decreasing white space. In one jurisdiction the footer text was in grey, reducing its impact. In reports for court (scientific style) the tables used to present results often had landscape orientation and narrow margins at left and right sides of the page. However, white space often existed in reports under the tables in which results were presented.

Font. The body text in reports of two jurisdictions used Times New Roman or Bookman Old Style (or a similar footed font). Four jurisdictions used Arial (although one jurisdiction's reports sometimes used Calibri or a similar sans serif font). In reports for police, the body text from both jurisdictions was in approximately 9 or 10-point font. The font size was usually 11-point font in the body text of reports for court. Only two jurisdictions used 12-point font. The reports for court of one jurisdiction were in 10-point font. The font size in tables and appendixes was often smaller than that of the body text (e.g., 10.5-point font). The font for meta-discourse in reports for court was even smaller than 8-point font in some instances (e.g., for an email address or for NATA accreditation details).

Structure and density of lists and tables. Lists and tables were used extensively in reports from all jurisdictions (with the exception of the reports for police from one jurisdiction). Lists and tables were used to present the items submitted for analysis and/or to report the findings and interpretations. As can be seen in Table 5, the reports of most jurisdictions contained lists or tables that were fairly easy to read according to the PMose/IKirsch document readability formula. The item lists of reports for court in legal style were typically presented in numbered or bulleted lists, while the lists of items in reports for court in scientific style were typically reported in tables, either with or without gridlines. The results and interpretations were most commonly presented in tables. Many lists of items and tables of results spanned numerous pages. Greater complexity of tables was generally associated with a greater number of items analysed and results reported. Three jurisdictions had tables of differing complexity across the range of reports received, but were most commonly written at a junior high school level. By contrast, the tables of one jurisdiction consistently scored a senior high school reading level or above. These tables provided comprehensive and concise information within a single page, but placed substantial demand upon reading ability.

Discussion

The purpose of this study was to examine current reporting practices for DNA expert reports in Australian jurisdictions and to assess holistically the readability of the reports. To do so, we considered various aspects of content and sequence, language, and format. Reports differed more across than within jurisdictions. Within jurisdictions, reports typically conformed to the same style in terms of content and sequence, language, and format. In analysing reports for readability, it was evident that scientists from each jurisdiction had attempted to anticipate and meet report-users' needs in different ways. For example, the reports of some jurisdictions included glossaries of terms, outlined methods and interpretation practices, or reported according to practice guidelines provided by Keane (2011) to meet the needs of the courts. The varied approaches suggested differing language ideologies (or assumptions about language), relating to the best way to assist police and the courts (Eades, 2010).

However, despite the efforts made in each jurisdiction to meet the needs of non-scientist report-users, the results of the analyses overall showed that particular aspects of the reports would likely pose difficulties for non-scientist report-users. Past research has validated the effectiveness of theory-driven approaches to readability enhancement (Feufel, Schneider, & Berkel, 2010; Hirsch, Clerehan, Staples, Osborne, & Buchbinder, 2009). Theory-driven approaches are less likely to result in idiosyncratic changes to report styles, than would be approaches based on usability testing with report-users (Mosenthal & Kirsch, 1998). Areas of difficulty in the reports and how they compare with those identified in reports of forensic comparison of glass are discussed before outlining some possible solutions, based on theory, to make reports more readable for non-scientists who use the reports.

Particular Issues for Readability

Content and sequence. Differences between reports from participating jurisdictions may reflect the evolution of report styles over time to meet local needs through consultation between laboratory staff and report users. Negotiation over time may have resulted in decisions such as placing information about methods of analysis in appendices as opposed to placing it prior to results. Alternatively, the practice of placing methods of analysis at the back of reports may have been influenced by the structure of certain scientific journals (such as *Nature*; Wu, 2011) that routinely locate methods at the end of articles. This issue reflects that observed in reports of forensic comparison of glass (Howes et al., 2014).

For writers of the reports, this structure may decrease writing time, because routine information is pre-prepared as appendices. For regular report-users, the report structure, if it is a familiar one, may facilitate quick location of specific information. This is because any structure that is repeatedly used allows readers to make predictions about the location of content within it (Burrough-Boenisch, 1999; Meyer, Marsiske, & Willis, 1993).

However, the structures of reports from some jurisdictions appeared to be extremely idiosyncratic. For example, attaching both a statement and a certificate to a scientific-style report was unusual, in that only one jurisdiction did this, and may reflect a compromise between requirements from the courts and best practice in the laboratories. In short, the logic of report structure was not always obvious and often was not made transparent through the use of explanations about the report contained within the report (meta-discourse). Given that reports seem to differ by discipline, report-users are potentially confronted by as many different styles of reporting as reports are issued for a given case.

With increasing use of DNA evidence over a range of case types, it cannot be assumed that all report-users regularly read DNA expert reports. There is no benefit to an idiosyncratic and disjointed report structure unless it is familiar to the reader.

Language. Readability statistics indicated that the conclusions of reports for court were written at a level considered *difficult;* reports for police were *fairly difficult.* Years of formal schooling associated with the conclusions of reports ranged from *high school* to *postgraduate*. The readability of appendices ranged from *difficult* to *very difficult.* This was similar to the degree of difficulty of reports of forensic glass comparison (Howes et al., 2014). The lexical density of reports when conclusions were written in sentences was generally at a level associated with standard written English (as opposed to the more difficult scientific English associated with some jurisdictions' reports of forensic comparison of glass; Howes et al., 2014). However, the lexical density of conclusions written in note form was high as a proportion of total text and did extend beyond the range associated with abstracts of journal articles from a range of disciplines (Gholami, Mosalli, & Nikou, 2012). As explained by Halliday (1993a), the difficulty of scientific writing for non-scientist readers is compounded by the routine use of scientific terms that are interrelated, such as when an explanation of one scientific term involves the introduction of others. This issue reflects that identified in reports of forensic comparison of glass (Howes et al., 2014).

A key area of disparity among jurisdictions was in the communication of strength of evidence. As has been acknowledged by many, this aspect of the reports is an area of potential confusion for non-scientists (Lindsey et al., 2003; Lynch & McNally, 2003; Martire, Kemp, & Newell, 2013; Martire, Kemp, Watkins et al., 2013). We identified the forms of expression used to indicate uncertainty and the weight of evidence in current use in Australian jurisdictions for DNA evidence. Uncertainty and the weight of evidence are currently reported differently by jurisdiction in both reports for police and reports for the courts, as is the case in reports of forensic comparison of glass (Howes et al., 2014). Providing expected frequency of DNA profiles in the population was more common in reports for court (legal style). Probability estimates or random match probabilities were more common in reports for court (scientific style). When hypotheses or propositions were presented, they were about the source of the samples. Reporting likelihood ratios was typical when DNA profiles were mixed, although one jurisdiction also reported likelihood ratios for single contributor profiles, and provided a conclusion indicating the degree of support for a specified proposition according to a verbal scale. These differences between jurisdictions reflect the lack of consensus as to which form of expression is best understood.

Format. Reflecting issues identified in reports of forensic comparison of glass (Howes et al., 2014), the use of font smaller than 12-point Times New Roman (or 11-point Arial) was common in appendices and for meta-discourse. Larger fonts are preferred by readers (Shrank, Avorn, Rolon, & Shekelle, 2007). Cramped text with single-line spacing is also problematic as it reduces the amount of white space and can appear overwhelming to readers (Doak, Doak, & Root, 1996). Text in appendices was often both small and cramped. While headings in the appendix typically appeared in bold font (as is appropriate to flag important terms (Doak et al., 1996), information was not grouped into manageable pieces (or information chunks), making the text appear even more overwhelming to readers.

In general, the reports of DNA analysis made extensive use of tables in comparison to the reports of forensic comparison of glass (Howes et al., 2014). The use of tables, as opposed to prose, requires different reading strategies of report-users (Mosenthal, 1996; Mosenthal & Kirsch, 1998). The majority of tables used were presented at a level that would be acceptable to most report-users, according to the scores obtained with the PMose/IKirsch document readability formula. However, it is important to recognise that the formula did not take into account the difficulty of tables that continued over multiple pages, and tables that had landscape rather than portrait orientation.

Implications for Writing Expert Reports

When writing according to required protocols, it can take time to bring about changes in reporting. It may not be considered acceptable within laboratories for individual scientists to write in ways that break from established norms, even if it makes for clearer presentation. This issue has been acknowledged in past research (Gal & Prigat, 2005). The following suggestions – based on theory and past research – aim to assist scientists to increase the readability of expert reports of DNA analysis, within existing reporting structures.

Content and sequence. Whilst the effort to write concisely is undoubtedly appreciated by report-users, writing concisely is not helpful if desirable information is not included or is difficult to locate. Despite increased use of DNA evidence, it cannot be assumed that all report-readers regularly use DNA expert reports. To orient the reader to the report, an indication of the nature of the case, what is included in the report, and where it may be found would be helpful. This could be provided in paragraph form or as a table of contents.

Similarly, whilst it undoubtedly makes sense for scientists to use appendices to report methods and procedures that are commonly used, and may make sense to regular report-users, it would make less sense to readers who are less familiar with reports to have to refer to an appendix outlining methods. If it is deemed desirable to use an appendix for this purpose, it would be best to specify (simply and briefly) within the main document the techniques used. In this way, readers can be alerted to the specific techniques used and can seek clarification in the appendix if necessary. It would be beneficial to make appendices more relevant to specific cases, eliminating from them any information that is unrelated to the particular case.

Inferences that can be drawn from results may be evident to scientists but are likely to be less obvious to non-scientist report-users (Britton & Gülgöz, 1991). A synthesised summary of the results obtained from the items examined may be extremely helpful for readers. For example, in serious cases when multiple samples taken from an item were examined, a paragraph summarising the findings for that item could be provided. This would decrease the cognitive load placed upon readers, by reducing the degree of difficulty of the reading task required (Mosenthal, 1996) from synthesising and interpreting information to locating information. Notes on interpretation and the potential limitations of DNA evidence in the case could also be clarified in many of the reports. Limitations were often mentioned, but were shuffled to the back in an appendix and interspersed with other information. It would be more helpful if this information could be placed immediately before or after the interpretation to which it applied (Doak et al., 1996).

Language. The appendices attached to reports from most jurisdictions contained scientific language that would be difficult for report-users to understand. The wording of appendices should be reviewed and simplified where necessary, so that undefined scientific terms do not appear in the glossaries aimed at clarifying other scientific terms. Appendices explaining methods should ideally be written at a level that could be understood by a reader with a Grade 7-9 reading ability in science. This is necessary because many personnel in the criminal justice system would not have studied science beyond the compulsory level (Grade 10; Howes et al., 2013). Further, grade levels indicated by the Flesch-Kincaid grade level may overestimate reading ability, so it would be best to make complex scientific information easier to read. However, it is important not to write to obtain a desirable grade score on a readability formula, as this may result in unnatural use of language (Klare, 1981). Readers prefer more natural use of language (Green & Olsen, 1988), and simpler words are not always better (Graves & Graves, 2003); correct scientific terms should be used and explained. Writing readable text means taking the reader from simpler known information to more complex new information (Britton & Gülgöz, 1991; Kintsch & van Dijk, 1978). By presenting information from the simple to the complex, text maintains coherence, even when complex information is presented.

It may be worth stating inferences that can be drawn from (numerical) likelihood ratios more explicitly (Britton & Gülgöz, 1991; Graves & Graves, 2003). For example, one jurisdiction explained the use of likelihood ratios by referring to a verbal scale indicating support or lack thereof for a given proposition (as described by Buckleton, 2005). Providing this context for use of likelihood ratios may be one way to make them more reader friendly. When a report makes the inference from the likelihood ratio explicit, it should decrease the chance of misinterpretation of the unfamiliar (and sometimes incomprehensibly large) number.

Format. It may seem desirable to report-writers not to create too long a report, to save paper and to avoid including irrelevant information. However, by condensing a great deal of complex information without explanation into a report of fewer pages it may be perceived by readers as more overwhelming (Doak et al., 1996). The explanatory information in appendices was not only densely worded, but in small font and cramped due to the use of single-line spacing. This is not ideal. Presumably page limits do not apply to expert reports. Text that is in 12-point font, spread out with 1.5 to 2.0 line spacing, and margins at the default setting of 2.54cm or greater, appears less cluttered and is easier to read (Doak et al., 1996).

Because the use of tables was widespread in DNA reports, they warrant special consideration. Where it makes logical sense to use separate tables, rather than making a table continue over a number of pages, this may be helpful to report-users. For example, where results are reported for multiple samples of a single item, it may be worth presenting a table for the results for that item, rather than incorporating such a table into a larger table. When tables must continue over a number of pages, it is essential that headings be used at the top of each page of the table, so that readers need not flip back to the first page of the table (Doak et al., 1996).

Limitations and Future Research

Many of the issues identified in reports of DNA analysis broadly reflected those identified in reports of forensic comparison of glass (Howes et al., 2014). This suggests that strategies provided to enhance readability may be applicable to reports of different scientific disciplines. Future research can examine how reports written according to these strategies impact upon readability and usability for non-scientist report users, in comparison with current reports.

We argued that the disjointed nature of reports would pose problems for report-users new to DNA reports but acknowledged that this may not be the case for regular report-users. However, it is possible that regular report-users also perceive as problematic the disjointed nature of reports, particularly if they use reports from a range of forensic scientific disciplines, for which reporting styles differ. Further research with report-users is necessary to assess the impact on perceived difficulty of reports posed by glossaries that contain both report-relevant and -irrelevant terms. Further research could also evaluate the extent to which report-writers would be burdened by outlining only terms and methods relevant to the particular case. In short, further research is needed to assess the perceived adequacy of current report structures for report-users, and the perceived issues with making changes to the current structures for report-writers.

Although we identified reporting trends for DNA evidence in Australian jurisdictions, evaluation of the forms of expression that were best understood was beyond the scope of this research. This is an ongoing issue and although a body of research has explored forms of expression and jurors' comprehension, it remains unresolved. Further research is needed to explore which forms of expression are best comprehended by police, lawyers, and judges.

When using the document readability measure to evaluate the difficulty of tables, we did not add document dependency scores each time a table extended to a new page. Had we done this, the majority of the table scores obtained would have been significantly higher, and would perhaps have resulted in over-estimated difficulty scores for tables. However, it is likely that the scores obtained for tables in this study under-estimate, to at least some extent, the difficulty for readers of using the multi-page tables.

Conclusion

The reporting of DNA evidence is complex for a number of reasons. These include the complexity of the processes involved, the terminology associated with explanations of it, and the need to facilitate understanding for non-scientists who use the information to make important decisions. Because DNA evidence is increasingly used in broader applications in the criminal justice system, the reports of DNA analysis need to be understood by greater numbers of non-scientists working in this arena. We used the theoretical framework of systemic functional linguistics to assess reports of DNA analysis holistically, in terms of content and sequence, language, and format. We identified some particular aspects of the reports likely to pose difficulties for non-scientist report-users. Based on theory and past research, we suggested ways in which reports can be made more readable for non-scientist report-users. These suggestions do not address the complexity inherent in DNA analysis, but instead use principles from linguistics, education, and psychology, to present complex information with greater clarity. Because readability can be seen as a prerequisite to comprehensibility, it is hoped that increasing the readability of reports can contribute to enhanced effectiveness of the criminal justice system.

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Part 3

Conclusions and Recommendations from Readability Studies

7

Response to Recommendation 2 of the 2009 NAS Report – Standards for Formatting and Reporting Expert Evaluative Opinions: Where Do We Stand?

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Abstract

Over four years ago, the 2009 US National Academy of Sciences report on forensic science was published, revealing that few formal standards existed in the forensic sciences. The second recommendation of the NAS report related to the language of reporting. This two-fold recommendation urged that templates for expert reports be developed and that the language and terminology of the reports and related expert testimony be standardised. This paper offers a response to Recommendation 2 of the NAS report and a research update. Since the release of the NAS report, Standards Australia has developed a set of forensic standards, including one for reporting. In light of Recommendation 2 of the NAS report and the Australian Standard for reporting, we outline current reporting practices of forensic science in the Australian context, and review research about the communication of forensic science, highlighting recent Australian research undertaken at two universities. We discuss the progress made to date in the development of best practice in expert reports and language use, introduce new directions for developing communicative excellence amongst forensic scientists, and suggest future research directions.

Response to Recommendation 2 of the 2009 NAS Report – Standards for Formatting and Reporting Expert Evaluative Opinions: Where Do We Stand?

More than four years have passed since the 2009 National Academy of Sciences (NAS) report, *Strengthening forensic science in the US: A path forward*, was released, critiquing the forensic sciences, and sending ripples around the forensic science community worldwide (e.g., Cole, 2010; Risinger, 2010). The report made thirteen recommendations, the second of which related to the language and structure of reporting (NAS, 2009). The first part of Recommendation 2 called for a proposed National Institute of Forensic Sciences (NIFS) to "establish standard terminology to be used in reporting on and testifying about the results of forensic science investigations" (NAS, 2009, p. 22). The second part of the same recommendation called for the NIFS to "establish model laboratory reports for different forensic science disciplines and specify the minimum information that should be included" (NAS 2009, p. 22). The purpose of this paper is to outline the current situation in Australia relating to this two-part recommendation, and to highlight recent psychological and social sciences research undertaken at two Australian universities that begins to address it.

In this paper, we begin with a brief outline of the organisational structure of forensic science in Australia to provide the context for the research presented. Next, rather than addressing the components of the recommendation in the order in which they appeared, we first discuss research concerning the form of expert reports in their entirety (the second part of Recommendation 2), because the language in reports influences the language used in courts. Research about the use of standard terms in reports and courts (the first part of the recommendation) follows. We then outline a project undertaken in Australian jurisdictions that aims to enhance the written and oral communication skills of forensic scientists. Finally, we summarise the progress that has been made to date and discuss future directions for research.

The Australian Context

Australia has a National Institute of Forensic Sciences (NIFS), which was established in 1991 and commenced operations in 1992 (Australia New Zealand Policing Advisory Agency [ANZPAA], 2010). Its role includes sponsoring and supporting forensic science research, facilitating information exchange, and coordinating quality assurance programs (ANZPAA, 2010).

Forensic sciences in Australia are organized by federal, state, and territory jurisdictions. There are six states (New South Wales, Queensland, South Australia, Tasmania, Victoria, and Western Australia) and two territories (Australian Capital Territory [ACT] and the Northern Territory) one of which (ACT) comprises a business unit of the Australian Federal Police jurisdiction (Australian Bureau of Statistics, 2012). The location of forensic science laboratories differs by jurisdiction. Whilst all are government laboratories, some are organised under the department of police or justice, while others are under the umbrella of health or attorney general's departments (Howes, Julian, Kelty, Kemp, & Kirkbride, 2014). In some jurisdictions, forensic chemistry and biology are within the one facility, while in others they are conducted in separate facilities.

The government laboratories in Australia are accredited with the National Association of Testing Authorities (NATA). To maintain laboratory accreditation, scientists within each laboratory are required to participate in internal or external proficiency testing (for example with Collaborative Testing Services, Inc.; see https://www.ctsforensics.com/) in each discipline in which they conduct forensic casework (NATA, 2012).

Standards Australia has recently released a set of four forensic science standards: (1) collection; (2) analysis; (3) interpretation; and (4) reporting (ANZPAA – NIFS, 2013). The standards are compatible with the International Organization for Standardization (ANZPAA, 2012; Standards Australia, 2013) to which the NAS Report refers (NAS, 2009, p. 21). Whilst the current standards apply to forensic sciences generally, discipline-specific standards to supplement these are forthcoming (ANZPAA, 2012). Because international standards for forensic science reporting are not currently available, the Australian Standards are of interest internationally among the forensic science community.

Research about Expert Reports and Report Templates

Background

In broad terms, communication is generally conceptualised as a two-way interactive process (Craig, 1999), wherein knowledge is contextual and meaning is constructed and negotiated (Campos, 2007). In a conversation, a listener can use contextual information provided by facial expressions, gestures, and feedback to enhance understanding. However, in formal contexts (such as a courtroom) to some extent, and in written communication, to a greater extent, these cues are less readily available (Dixon & Bortolussi, 2001).

It has been argued that the majority of formal communication about forensic science occurs through written reports (as opposed to court testimony), both in adversarial and inquisitorial legal systems (Rothwell, 2010; Broeders, 2003). Because most forensic science is formally communicated in written reports, the content of reports as a whole is important and provides context for readers.

The readability of reports is one important dimension of this written communication, as it can be considered a prerequisite to comprehensibility (Badarudeen & Sabharwal, 2010). Readability depends upon not only the text, but also the reader, and the interaction between the reader and the text (Graves & Graves, 2003). Scientific language differs from general language in a number of ways (Halliday, 1993), adding to the difficulty for non-scientists in reading and understanding expert reports. In short, a report written for a fellow expert, no matter how clearly expressed, is unlikely to be suitable for a non-expert to read and understand (Britton & Gülgöz, 1991).

Readability of Expert Reports for Non-Scientists

Readability can be assessed both quantitatively (e.g., using a readability measure such as the Flesh-Kincaid formula) and qualitatively (e.g., by considering aspects of content and sequence, language, and format from the perspective of the intended reader). Different approaches to assessing readability from various theoretical perspectives have each included one or more of the categories of content and sequence, language, and format (Howes, Kirkbride, Kelty, Julian, & Kemp, 2014). Holistic assessments of readability can include both qualitative and quantitative assessment (see e.g., Hirsh et al., 2009), wherein the use of readability formulas may be one aspect of language that is assessed.

A study of 111 conclusions, written in 2011 as part of an international proficiency test of forensic analysis of glass, found that the conclusions were written, on average, at a level of reading difficulty associated with a tertiary education (Howes, Kirkbride, Kelty, Julian, & Kemp, 2013). This level is expected when experts communicate with each other, but is not suitable for a general audience (even if tertiary educated; Britton & Gülgöz, 1991). The results of the study showed a number of issues that commonly occurred in conclusions: sentences were long; assumptions and the basis for the scientific opinion provided were not stated; and results and interpretation were presented in a single sentence, making it difficult to ascertain where results ended and interpretation began (Howes et al., 2013). Overall, the results of this study suggested that the complexity of experts' conclusions was not limited to the terms used to express associations of evidence, but involved features of the writing overall (Howes et al., 2013).

To explore the notion that the features of the writing demonstrated in expert reports impacted upon difficulty in comprehending them, the readability of complete expert reports recently submitted in Australian jurisdictions was holistically assessed in two additional studies. The first study analysed the readability of reports of forensic glass analysis (Howes, Kirkbride et al., 2014). The seven jurisdictions in Australia offering forensic glass analysis were invited to participate in the study by providing de-identified copies of recent reports of forensic glass analysis. All seven laboratories agreed to participate and each sent 9-15 reports. Because it has been noted that DNA evidence in particular can be difficult for non-scientists to understand (Cashman & Henning, 2012), the second study repeated the first using DNA reports (Howes, Julian et al., 2014). Laboratories in six of eight Australian jurisdictions participated by sending a selection of recent, de-identified reports of DNA analysis. In both studies, quantitative and qualitative approaches were used to assess readability in the categories of content and sequence, language, and format. The results are discussed below by category (content and sequence, language, and format) in light of Recommendation 2 of the 2009 NAS report and the Australian Standard for reporting.

The content and sequence of expert reports. In terms of accepted scientific discourse (Hagge, 1997), it makes sense to include certain categories of information in any scientific report. For example, journal articles typically use a structure of introduction, method, results, and discussion (IMRAD; Wu, 2011). Comprehension is facilitated when readers can navigate a predictable structure to locate information they need (Burrough-Boenisch, 1999), and texts proceed from the simple to the complex or from known to new information (Britton & Gülgöz, 1991; Kintsch & van Dijk, 1978). Whilst the NAS Report and the Standards Australia reporting guidelines did not cite research that provided a rationale for the proposed report contents, the research outlined in this paper can assist in providing such a rationale, embedding this tradition of effective scientific communication within the body of research on communication.

The NAS Report stated that reports should contain the following sections: methods and materials, procedures, results, and conclusions. In addition, they should include "sources and magnitudes of uncertainty in procedures and conclusions" (NAS, 2009, p. 21). Standards Australia (2013) suggested that content may vary according to report purpose, but listed a number of features that must be included (e.g., date of issue, case identifier) for all written reports, and other information that should be included in reports for legal proceedings (e.g., collection and continuity of material, qualifications and experience of the scientist).

Qualitative assessment of reports of glass and DNA revealed that the main sections suggested by the NAS report and Standards Australia were typically present in reports. However, analysis also revealed some potential issues in the content and sequence of reports. Reports of glass comparison rarely provided an outline of the context or purpose of the report; and overall the reports provided only limited information about what scientists did and why (Howes, Kirkbride et al., 2014). Similarly, for reports of DNA analysis, often the reports lacked a stated aim or purpose, the method section was out of sequence because it was often located in an appendix, and there existed insufficient elaboration – results were not summarised into a coherent whole and links were not made for the reader (Howes, Julian et al., 2014). For example, when a number of items said to belong to a particular suspect were examined, results tended to be presented item-by-item. The fact that no overall summary was presented (e.g., regarding the findings relevant to a particular suspect) could contribute to difficulties for non-scientists in understanding the reports. The researchers recommended including more information, even if briefly, to ensure that the non-scientist reader could follow the scientists' logic, enhancing understanding of the decisions made, procedures followed, results obtained, and interpretations thereof (Howes, Julian et al., 2014: Howes, Kirkbride et al., 2014).

The format of expert reports. The NAS report did not make explicit recommendations regarding the specific format of reports. However, it can be inferred that the expected format would accord with the section headings supplied in the report (specifically, methods and materials, procedures, results, and conclusions; NAS, 2009). The suggested section headings were not dissimilar to the IMRAD headings often used in scientific journal articles (i.e., introduction, method, results, and discussion [IMRAD]; Wu, 2011). Standards Australia's (2013) reporting guidelines stated that the format of reports may vary by jurisdiction and purpose.

In the glass and DNA reports assessed, each jurisdiction had uniformity in its presentation of reports by discipline (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). However, the format of most jurisdictions' reports of forensic glass analysis was visually cramped with limited use of white space and there were few headings to aid readers in navigating the contents of reports (Howes, Kirkbride et al., 2014). The DNA reports often contained multi-paged tables that added to reading complexity. Following their analysis of these reports, the researchers suggested that headings should be provided on each page of a multi-paged table, and that key information from such tables should be summarised in text following the table (Howes, Julian et al., 2014). These types of accommodations make reports appear more user-friendly and less likely to be perceived by non-scientist readers as overwhelming (Doak, Doak, & Root, 1996).

The language (in general) of expert reports. The 2009 NAS Report recommended the use of standardised terminology, particularly for expressing evaluative opinions. The guidelines provided by Standards Australia stated that terminology used should be readily understood by non-specialists, or otherwise clearly defined (Standards Australia, 2013).

The two studies outlined above revealed that this was not often the case. Readability statistics for the complete glass reports showed that they were written at a level associated with expertise in forensic chemistry. The difficulty level of most reports overall was *difficult* and required a university education (as measured using the Flesch-Kincaid grade level and the Flesch Reading Ease formulas). Moreover, a university education would not be particularly helpful in facilitating understanding, unless it was in a relevant field of science. This difficulty level was due in part to the use of scientific discourse and unexplained assumptions inherent in the reporting style (Howes, Julian et al., 2014; Howes, Kirkbride et al., 2014).

The reports contained sentences that were long and specialist terms (and general terms with specialist meanings) were not often defined in either type of report (Howes, Julian et al., 2014; Howes, Kirkbride et al., 2014). Although Standards Australia (2013) recommended the use of glossaries appended to the report for terms not in common usage, analyses also showed that glossaries of terms were included in the reports of some – but not all – jurisdictions (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). The glossaries of some jurisdictions used additional undefined specialist terms within the definitions themselves. Some non-specialist terms used with specialist meanings were not defined. The glossaries of some jurisdictions provided definitions of terms that had not been used in the bodies of reports.

In response to these observations, the researchers argued for definitions of specialist terms in text in the first instance. It was suggested that defined terms should be identified in some way (e.g., highlighted in bold) throughout the report, to signal to readers that they appeared in the glossary (Howes, Julian et al., 2014). It was also argued that because the readers of reports (police investigators, lawyers, judges) and those who hear courtroom testimony (judges and jurors) cannot be expected to have a tertiary education in science, the definitions should be written at a level suitable for a reader with mandatory education (to a junior high school level) in science (Howes, Kirkbride et al., 2014).

Development and Use of Report Templates

The results of the two studies of expert reports indicated that they were consistent by jurisdiction and intended audience (police or courts) in content and sequence, language, and format (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). It appeared that templates had been developed at the laboratory level, as appropriate to the requirements of police and courts of the particular jurisdictions. For example, in some jurisdictions, separate reports were prepared for police and for the courts, whereas in other jurisdictions a single report was used for both audiences.

Although it seems that templates exist in forensic biology and chemistry, they may not yet exist in all disciplines. Following a multidisciplinary workshop about expert evidence, Found and Edmond (2012) presented an example of a pattern evidence report flow that could be used by a wide range of forensic scientific disciplines. For forensic scientists wishing to develop or review their reporting templates, the structure outlined by Found and Edmond (2012) offers a practical and useful structure to consider, informed by scientists, lawyers, and psychologists. Sections suggested by Found and Edmond (2012), but not typically included in Australian jurisdictions' reports of forensic analysis of glass or DNA were: an executive summary; the request for examination that was made; and a section about the case contextual information received by forensic scientists.

Similarly, the results of a recent large-scale US study that analysed the content domains of 421 report templates for a broad range of forensic disciplines, and from a wide range of forensic agencies, revealed that many reports were very brief and omitted sections that would arguably be important to accurate understanding of the report. The missing sections included: methods of analysis and details of procedures used; data generated by testing; discussion of results; limitations; and an executive summary (Siegel, King, & Reed, 2013). Of interest, however, was that when compared with the guidelines for content provided by various agencies, the reports closely corresponded in content with those guidelines (Siegel et al., 2013). This indicates that further consideration of best practice in reporting by advisory bodies is warranted.

Standards Australia (2013) suggested that differences in form and content of reports may be appropriate depending upon the purpose and content of reports. Siegel et al. (2013) noted that in the 421 US expert reports examined, content differed by forensic discipline and by case context. However, as more Australian states and territories adopt Uniform Evidence laws (Odgers, 2012), and as the forthcoming forensic standards for each discipline are released (ANZPAA, 2012), it may be that the differences in jurisdictional reporting practices decrease.

Research about the Language of Conclusions

Background

The language used to formulate and communicate expert conclusions (also known as evaluative opinions) has been a topic of particular interest for the forensic science community (e.g., Aitken, 2012). The first part of Recommendation 2 (NAS, 2009) called for the establishment and use of standard terminology in reporting results; however, the realisation of this goal has proven more difficult than might first have been anticipated.

In a review of the language of reporting, Jackson (2009) presented an extensive list of terms in use to report the degree of similarity of dissimilarity observed between a control sample and a sample from a crime scene. The list was based on available research evidence as well as his extensive experience as a laboratory scientist. Whilst Jackson acknowledged that some of the variability in the language of reporting could be accounted for by differing strength of evidence, a recent study of the language of conclusions written as part of an international proficiency test added to the completeness of this account. Specifically, it was found that a wide range of terms (over 40 combinations) was used internationally to express very similar inferences of negative findings from a comparison (Howes et al., 2013).

Recommending the use of standardised terms, as does the NAS report (2009), implies that meaning is contained within words. In contrast to this, a constructivist understanding of communication views the reader or listener as an active constructor and negotiator of meaning (Campos, 2007). From a theoretical perspective on language and communication, the idea that words contain singular meanings that can be transmitted accurately from one person to another (i.e., a transmission model of communication) is considered to be a limited account of human communication (Craig, 1999). According to this view, words do not inherently contain meaning. Rather, language is a tool for making meaning (Halliday & Martin, 1993). In constructivist views of communication, the idea of singularity of meaning inherently contained in words is viewed as a flawed assumption. From this perspective, the idea of assigning standard definitions to terms and assuming that others will infer the same interpretation is not likely to offer an adequate solution. This was amply demonstrated by McQuiston-Surrett and Saks (2008).

In their US study, McQuiston-Surrett and Saks (2008) found that the terminology recommended by the American Board of Forensic Odontologists (ABFO) used to express the probative value or the strength of association of evidence was weighted differently by mock jurors than the meanings intended by scientists (McQuiston-Surrett & Saks, 2008). Odontologists used the term “match” to indicate similarities only in class characteristics (i.e., a low degree of correspondence); mock jurors interpreted “match” as having a high degree of correspondence, rating it at 86.0%. Conversely, the term “reasonable scientific certainty”, the highest correspondence that forensic dentists could assign was rated by mock jurors as having just 70.6% correspondence and was rated as having the third lowest level of correspondence of the four terms evaluated.

The study about the use of standard terms in forensic odontology by McQuiston-Surrett and Saks (2008) highlighted the potential pitfalls of selecting terms, assigning official meanings, and using them in courts of law. Although the ABFO subsequently changed its recommended terminology (see ABFO, 2013), the study has implications for scientists of other forensic scientific disciplines wishing to adopt standard terms in line with the recommendation of the NAS Report.

Expression of uncertainty. Evaluative expert opinions, which acknowledge the inferential reasoning process involved in attempting to attribute a *sample* to its *source* (as opposed to deductive processes which reason from a *source* to a *sample*), necessitate the communication of uncertainty (Berger, 2010). Uncertainties can be expressed in many different ways including expected probabilities, frequencies and likelihood ratios. In very simple terms (for detailed discussions see Brase, 2002, and Koehler, 2001a) probability expressions might describe the percentage chance of some event (e.g., a 5% chance that the reference and questioned samples would share the observed level of similarity by chance alone). These can also be formulated using numbers between 0 and 1 (a 5% chance can also be expressed as a .05 chance). Relative frequencies express how often something might be expected to occur in a population (e.g., in a particular city, five times in 100 the suspect and questioned samples would share the observed level of similarity by chance alone).

Likelihood ratios reflect the ratio of two probabilities: (1) the probability of the evidence under one (e.g., prosecution) hypothesis (H_1) divided by (2) the probability of the evidence under a complementary (e.g., appropriately formulated defence) hypothesis (H_2; discussed at length in Fenton, Berger, Lagnado, Neil & Hsu, 2013). For example, if the evidence were regarded to be 25% probable if H_1 is true (that the suspect and questioned samples shared the same origin) and only 5% probable if the alternative hypothesis is true (H_2, that the suspect and questioned samples came from different origins), the likelihood ratio for the evidence would be 25/5 = 5. This likelihood ratio could then be communicated as follows: “the correspondence between the suspect and questioned samples is five times more likely when H_1 is correct than when H_2 is correct”.

The example of the likelihood ratio provided above (the evidence is *five times* more likely when H_1 is true than when H_2 is true) is a numerical likelihood ratio. An equivalent verbal formulation might state (depending on the scale of verbal equivalents to be used) that the evidence offered *weak or limited support* when H_1 is true compared to when H_2 is true (as per the *Standards for Numerical and Verbal Expression of Likelihood Ratios*, Association of Forensic Science Providers, 2009).

It is evident that the likelihood ratio format is complex in comparison to the probability and frequency expressions. Despite the complexity of likelihood ratios, it has been convincingly argued that they are the logically correct way to present the expert evaluative opinions, which result from processes of inferential reasoning, as is the case with much forensic science evidence (Berger et al., 2011). However, not all agree that the inevitable consequence of this is for likelihood ratios to be presented to courts at trial. A recent debate regarding the issue of expressing evaluative opinions made clear that some members of the legal community advocate for the use of frequencies rather than likelihood ratios; arguing that these are more likely to be understood by non-scientists (Ligertwood & Edmond, 2012).

Indeed, at least one study has supported a cautious approach to the use of likelihood ratios at trial by demonstrating that they were not necessarily well understood by defence lawyers or judges. In fact, even the forensic scientists in the study (albeit with varying levels of expertise) at times misunderstood the meaning of the evidence, although they scored higher on comprehension than did the non-scientist participants in the study (De Keijser & Elffers, 2012).

Furthermore, it is important to note that the necessity for verbal formulations of likelihood ratios arose not only as a consequence of the general acknowledgement that numerical uncertainties can be difficult to interpret (as discussed above, see also Koehler, 1996; 2001b; and Thompson, 1989, for seminal research in forensic contexts), but also by virtue of the characteristics of some forensic science disciplines. Specifically, some forensic science domains currently lack sufficient data to assign reliable numerical likelihood ratios. Research considering these dimensions of communicating uncertainty broadly suggests that caution is warranted in endeavouring to meet the NAS recommendation to standardise terminology for reporting and testifying expert conclusions.

Expression of uncertainty in Australian jurisdictions. Research revealed that although a singular standard set of expressions had not been adopted nationally for forensic glass or DNA analysis in Australia, terminology was used consistently within jurisdictions to express evaluative opinions (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). Some jurisdictions favoured the use of likelihood ratios (for both glass and DNA analysis) and included them in reports. In reports of forensic glass analysis, the use of a verbal scale as opposed to a numerical likelihood ratio was not uncommon, but the propositions considered, the scale used, and the basis for the scale were not always provided (Howes, Kirkbride et al., 2014).

In DNA analysis in particular, scientists within jurisdictions used terms consistently and the differing use of terms between jurisdictions appeared to depend upon whether or not likelihood ratios were calculated, whether such likelihood ratios were reported, and the ways in which they were reported. For example, most jurisdictions reported likelihood ratios for cases in which mixed profiles of DNA were obtained (with or without the use of verbal scales), but otherwise it seemed that only two jurisdictions routinely reported likelihood ratios in their expert reports, and of these one provided a verbal expression to accompany the numerical form (Howes, Julian et al., 2014). These findings confirmed that consensus on the issue has not been reached, and suggested that scientists reported in ways acceptable to courts at a jurisdictional level. This is consistent with the guidelines set out by Standards Australia (2013). However, it is less compatible with Recommendation 2 of the NAS report, suggesting that standard terminology should be used. It suggests the need for more research to address the first part of Recommendation 2.

Non-Scientists' Interpretation of Evaluative Expressions

Before consensus can be reached and standard terms adopted, it is important that research be undertaken to determine whether the terms are likely to be well-understood by key decision makers (police, lawyers, judges, and jurors) who encounter them in the criminal justice system. Indeed, cognitive scientists have long been interested in understanding how decision makers interpret and respond to probability statements across various contexts of evaluation (for a brief review see Martire, Kemp & Newell, 2013).

Probability statements. As an example, work by Gigerenzer et al. (2005) examined interpretations of probabilistic weather forecasts asking participants what was meant by the statement that there was a "30% chance of rain tomorrow". Participants' choices from the available multiple choice options revealed not only that understanding of the statement varied by geographical region (participants were recruited from five different capital cities), but also that the correct interpretation was only preferred in one of these locations (New York). The authors attributed differing performance across locations to differing levels of familiarity with probabilistic forecasts, which were favoured in New York, but not standard in other cities. This suggests that the individual experiences of lay decision makers may be just as important to their interpretation of the expert evidence as is the way in which that evidence is expressed.

Similarly, researchers have investigated interpretations of uncertain statements in the Intergovernmental Panel on Climate Change (IPCC) reports in order to understand how the public perceive climate evidence provided by expert scientists (Budescu, Broomell, & Por, 2009; Budescu, Por, & Broomell, 2012). These studies revealed that participants' numerical estimates of the probability expressions used in the report differed significantly from the values ascribed by the experts. Notably, these differences occurred despite the fact that participants were provided with the guidelines underpinning the expressions. It was also demonstrated that interpretations varied both within and across individuals – making the use of probability statements a very imprecise method for communicating important information.

Likelihood ratios. Given the push towards adopting likelihood ratios on the basis that they are the most logically appropriate means of communicating expert evaluative opinions in the forensic sciences (Aitken et al., 2011), it is also important to specifically consider how decision makers respond to likelihood ratio expressions. Yet research focusing on comprehension of likelihood ratios (both before and after the NAS report) has been quite limited and predominantly considered the use of verbal equivalents to numerical formulations.

Prior to the NAS report, Nance and Morris (2005) examined various methods of presenting DNA random-match probabilities (RMP) and laboratory error rates. In their experiment, participants (judges and jurors) were asked to rate the probability of the defendant's guilt based on one of three forms of the RMP: frequency (e.g., 1 in 40,000 chance of a coincidental match), a likelihood ratio (e.g., 40,000 times more likely to match if the accused is the source of the crime scene sample than if he is not), or a chart which provided translation of hypothetical initial beliefs (prior probabilities) to final beliefs (posterior probabilities) given the likelihood ratio presented. Guilt estimates were found to vary significantly depending on the format of presentation for the RMP. Follow-up analyses revealed a statistically significant difference between the frequency format (which resulted in the most conservative belief updating) and the chart format (resulting in the least conservative change). The likelihood ratio fell roughly between these two conditions and led authors to support their use in courts over frequencies, although it was noted that even in the LR conditions, participant judgements were not consistent with normative (Bayesian) models of belief updating.

Likelihood ratios and the weak evidence effect. In the wake of the NAS report, Martire and colleagues (Martire, Kemp, Watkins, Sayle & Newell, 2013) began by examining the interpretation and verbal equivalence of likelihood ratios formulated in accordance with the recommendations of the AFSP (2009). Specifically, whether: (1) the belief-change (from initial to final belief in the likely guilt of the suspect) of 620 mock-jurors corresponded with the experts' evaluative opinion regarding the strength of the evidence, and; (2) the belief-change resulting from equivalent verbal and numerical formulations of differing strengths (low, moderate and high) were commensurate. The results of this first study revealed that numerical and verbal likelihood ratios resulted in statistically equivalent amounts of belief-change when the evidence strength was moderate or high. However, when evidence strength was low, numerical expressions resulted in significantly greater belief-change than did verbal expressions.

Moreover, when participant perceptions of evidence strength were compared to the experts' perceptions, extremely large discrepancies were observed. For example where the expert testified that the evidence strength under H_1 was 495,000 times that under H_2, participants reported a median perception of the evidence strength under H_1 that was just 1.5 times that under H_2. A final, unexpected result of the study was the observation of a robust *weak evidence effect* in the low-strength verbal formulation. A weak evidence effect occurs when evidence which weakly supports one proposition (e.g., H_1) is misconstrued by the decision maker as evidence weakly supporting the alternative proposition (H_2; in forensic contexts see Petty & Cacioppo, 1996; McKenzie, Lee & Chen, 2002; Smith et al., 1996).

Clearly, a weak evidence effect is undesirable in a forensic setting, where it essentially suggests that jurors might misinterpret expert forensic science evidence incriminating the accused as though it is exculpatory. Consequently, questions regarding the reliability of this effect were examined by the researchers in a second study, this time including weak evidence supporting either the prosecution or the defence versions of the crime (Martire, Kemp, Watkins et al., 2013). The responses of 538 participants revealed an interesting asymmetry in the weak evidence effect resulting from low-strength verbal expressions of likelihood ratios, such that the effect was not evident where the expert testified to evidence supporting the defence case. Rather, the effect was limited to the context of weak prosecution evidence. Although this finding reduces potential concern regarding the rights of the accused, it still raises questions about the efficacy of the likelihood ratio, and verbal equivalents for communicating evaluative expert opinions to lay decision makers.

Notwithstanding the potential impact of these findings, they offered little in the way of effective alternative methods for communicating evaluative opinions. The researchers also sought to examine the relative performance of four different methods for communicating evidence strength with regard to two competing hypotheses (Martire, Kemp, Sayle & Newell, in press). Four hundred and four participants were asked to update their beliefs with regard to the guilt of the defendant on the basis of an evaluative expert opinion regarding low- or high-strength evidence presented in: (a) a numerical likelihood ratio; (b) a verbal likelihood ratio; (c) a table including verbal and numerical translations of all categories of evidence strength covered by the AFSP scale (i.e., likelihood ratios from 1-10 times to >1,00,000 times); and (d) a visual scale with a neutral midpoint and the value of the evidence plotted between the two competing hypotheses located at either end point.

Results indicated that when evidence strength was high, the four different presentation formats were equivalent. However, when evidence strength was low, numerical expressions resulted in significantly greater belief-change than was observed in the other conditions. These results were largely underpinned by differences in weak evidence effects, which varied across conditions. Specifically, on average, the now robust weak evidence effects in the low-strength verbal condition were replicated, this effect was minimal (and not statistically significant) in the visual scale and table conditions, and was non-existent in the numerical condition.

Although the mechanism driving these differences across conditions remains unclear, the available evidence suggests that numerical expressions are the least ambiguous of all likelihood ratio formats trialled, resulting in the most reliable belief-change (compared to expert intentions) and is also the least subject to weak evidence effects. Similarly, in keeping with the previous study by Martire, Kemp, Watkins et al. (2013), the perceptions of evidence strength stated by participants diverged substantially from the perceptions of the expert. This finding suggests that important aspects of the evaluative opinion may be lost or obscured to lay decision makers by the likelihood ratio expression.

Development and Use of Standard Terms

Overall, the evidence regarding the communication of uncertainties in general, and the impact of likelihood ratios in particular, suggest that the effective communication of information regarding evidence strength remains elusive. Logical coherence of likelihood ratio formulations, and the desire to ease interpretation via the use of verbal equivalents, has failed to provide clear lines of communication between expert forensic scientists and lay decision makers. Indeed, if anything, the evidence available to date suggests that the presentation of likelihood ratios to lay decision makers results in suboptimal belief updating, and under certain circumstances can give rise to errors in reasoning that have the potential to undermine just decision making.

Research about the Communication Skills of Forensic Scientists

Background

Although the recommendations of the NAS report refer specifically to the language of expert reports and testimony, forensic scientists also communicate to non-scientists through various other channels in both the investigative and trial or inquest phases of most criminal or coronial matters. In addition to issuing written reports to police, lawyers or coroners, forensic scientists also commonly discuss verbally their interpretations of results (whether it be their own work, or that of colleagues) with criminal justice and lay personnel in the course of their work. Such verbal communication includes discussions and debriefing at crime scenes, during triage processes at forensic laboratories, at formal or informal case briefings or meetings, and in teleconferences or by video link to policing agencies and courts (Kelty, Julian, & Ross 2012).

Whilst the forensic sciences have the potential to meaningfully contribute to fair and just criminal justice outcomes and to help establish links to crimes (Ribaux et al., 2013), studies have demonstrated that forensic expertise is not used to its potential. This underuse of forensic science has been shown to contribute to ineffective police investigations (Kelty, Julian, & Hayes, 2013) and has been a significant factor in wrongful imprisonments in the US (Gould et al., 2013; Mnookin, 2010) and worldwide (Sangha, Roach, & Moles 2010; Kaufman, 1998). Recent collaborative research in Australia has found one of the reasons the forensic sciences (and forensic medicine) are used poorly in criminal cases, and in serious criminal matters in particular, relates to a the difficulties for police officers and lawyers in understanding the verbal and written communication by forensic scientists. Communication difficulties and miscommunication can result in lack of trust and poor working relationships between scientists, police and lawyers (Julian, Kelty, & Robertson, 2012; Kelty, Julian, & Hayes, 2013; Kelty, Julian, & Ross, 2012). These findings complement the recommendation of the NAS report, which prioritises improvements to formal reporting practices, by suggesting that good communication about forensic science be prioritised more broadly.

In their seminal work, Kelty, Julian, and Robertson (2012), explored the cognitive, social and leadership attributes (often referred to as non-technical 'soft skills') of Australia's top crime scene examiners (CSEs). This research showed that the top 18 CSEs across Australia had clearly identifiable cognitive, social, and leadership attributes. In addition to high-level technical knowledge, the top CSEs had good problem-solving and negotiation skills, and advanced written, verbal and interpersonal skills. Interviews with over 100 police and forensic practitioners revealed that CSEs with high-level professional attributes impacted profoundly and positively upon their work. Top CSEs had more co-operative working relationships with police, lawyers and other forensic practitioners.[1] Police investigator participants stressed that CSEs with good negotiation skills, assertiveness, and advanced written, verbal and interpersonal skills had a significant impact on the direction of major crime investigations.

When police were able to have better communication with CSEs, they developed stronger trust and confidence in the CSEs' work and used their findings and opinions more often to guide investigations. Even when the CSE's evidence and opinion countered what

[1] By co-operative relationships, we mean working collegially, with professional relationships and boundaries in place.

investigators were thinking, the investigators stated they were more likely to consider what they thought were ‘counterintuitive propositions’ when they had more faith in the abilities of CSEs. In short, scientific expertise was more valued by police and lawyers when forensic scientists communicated assertively, wrote well, and were teamwork oriented.

Further, the senior detectives who took part in this research said that CSEs with good communication skills had an enormous impact upon staff resource allocation in the vital first stages of a major crime investigation. Senior detectives reported that after a few years they came to know who the best CSEs were, as they saw them at crime scenes and in court and read their reports. When CSEs with good communication and technical skills were present, detectives could entrust the processing of a crime scene to a CSE and start other tasks, such as door-knocks or debriefings with other investigators. When CSEs with poorer skills attended, detectives overwhelmingly believed the scene would not be processed well and that they could not leave the CSEs “unmanaged” (Kelty, Julian, & Robertson, 2012).

For forensic science to contribute effectively to the criminal justice system, this research highlighted the necessity for forensic scientists to possess good communication skills in addition to their technical skills. Furthermore, preliminary findings from ongoing research suggest that it is not only CSEs who need high level communication skills, but any forensic practitioners who work within the criminal justice system and interact with non-scientists.

Enhancing the Communication Skills of Forensic Scientists

In 2013, the third author of this paper commenced working with several Australian police jurisdictions to translate the research on top performing CSEs into a targeted recruitment strategy and early career professional development program for field operational forensic scientists.[2] The professional development program is currently set to commence its pilot stage and comprises a three to five year early career skills-enhancement program for entry-level forensic practitioners. The rationale for the professional development program was that working conditions are changing such that forensic practitioners across Australasia increasingly work in multidisciplinary teams. In the field, this occurs both when mobile forensic teams are deployed to local crime scenes, and when disaster identification teams are deployed inter-state or internationally. Within laboratories, multidisciplinary teamwork is increasingly required to receive, prioritise and jointly triage forensic casework submissions. Given these challenges, it makes sense to equip forensic practitioners with the high-level communication skills, in addition to technical skills, necessary to excel in forensic science (Kelty & Julian, 2014).

The professional development program is an evidence-based professional skills enhancement program that aims to develop highly skilled forensic practitioners through: (1) structured courses and workshops; (2) online self-paced learning modules; and (3) workplace opportunities, such as court observations, and participation in multidisciplinary rapid mobile team deployments. The evidence-based workshops component of the professional development program aims to enhance skills in specific domains, including: conflict resolution; complex problem-solving in collaboration with others; report-writing; and verbal communication. The specific goal of the report-writing and verbal communication component of the professional development program is to ensure that the verbal and written messages provided by forensic scientists can be accessible to non-scientist audiences. Included in the program are tasks designed to equip scientists with the skills to take complex ideas and communicate them in everyday or lay terms (Kelty &

[2] For a discussion of the entry-level recruitment strategy for field forensic scientists, see Kelty (2012) and Kelty and Gordon (2013).

Julian, 2014). The pilot program includes evaluation, to track enhancement in forensic scientists' communication skills.

Achievements to Date and Future Research Directions

Expert Reports and the Development and Use of Templates

The NAS Report recommendation, to develop and use reporting templates, reflects recognition of the importance of the overall report in providing context for readers. Recent research suggests that the laboratories in Australia that offer forensic analysis of glass or DNA are using reporting templates developed at the jurisdictional or laboratory level (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014) and largely conform to guidelines set out by Standards Australia (2013) and Found and Edmond (2012). Similarly, research indicates that US reports largely conform to existing US guidelines (Siegel et al., 2013). However, depending upon the purpose of the reports, some laboratories may need to increase the amount of identifying information on reports or the level of detail provided in the body of reports. Although currently, reporting styles are not uniform across Australia, similarity may increase over the coming years given the movement towards more similar legislation across Australian jurisdictions and as discipline-specific forensic standards are developed by Standards Australia.

To ensure that the reports evolve in a direction that provides sufficient scientific detail and precision, and meet the needs of non-scientist report-users, research that explores the perceptions of report-writers and users is needed. The development of the discipline-specific forensic standards should be informed and supplemented by relevant research. Research currently underway at the University of Tasmania aims to address this so that scientists' and practitioners' views, in conjunction with theory-based approaches, can help to shape the development of writer- and reader-friendly expert reports. It is hoped that by addressing the content and sequence, language, and format of reports overall, the effective communication of complex science in a justice context can be facilitated. At the same time, the second part of Recommendation 2 of the NAS Report can be more completely addressed.

Evaluative Language

The NAS recommendation to establish standard terminology to be used in reporting on and testifying about the results of forensic science investigations has given rise to considerable activity both within and outside the forensic sciences. Specifically, publications setting standards (AFSP, 2009) and sharing opinions (Aitken et al., 2011) suggest that a consensus is forming with regard to how logically appropriate expert evaluative opinions should be expressed. Moreover, forensic scientists have engaged with various academic disciplines (including law and the cognitive sciences) to facilitate debate and foster research testing their proposals for the future. For example, see the special issue of the *Australian Journal of Forensic Sciences* presenting papers from a two-day symposium on the topic of ‘Impressions and Expressions: Expert Evidence in Reports and Courts’, edited by Professor Gary Edmond. Overall, this multidisciplinary engagement has resulted in a greater collaboration and increased awareness of some of the limitations associated with current proposals, as well as the challenges ahead.

For the future, these interdisciplinary relationships will need to be maintained and expanded in order to try to resolve some of the discrepancies between expert intentions and lay interpretations, to validate the appropriateness of the proposals still in formulation, and to form a firm foundation upon which communication in the forensic sciences can be reformed to meet the NAS recommendations.

Enhancing Communication Skills

The recently developed professional development program for entry-level forensic scientists explicitly acknowledges that communication skills are an important component of the desirable attributes of top-performing forensic scientists. The pilot program marks a new development in approaches to communication in forensic science. It represents a holistic approach to the ongoing development of communication skills for forensic scientists. Whilst the pilot program is soon to be released, it remains to evaluate and modify the program to ensure that it meets the needs of the participating jurisdictions and the non-scientist audiences for the communication.

Conclusion

In this paper, we outlined the state of expert reports in Australia in relation to Recommendation 2 of the 2009 NAS Report and recently published forensic standards. We reported recent research undertaken at two Australian universities that aims to address the same recommendation. Overall, current Australian reports of forensic glass and DNA analysis reflect some of the features suggested by Recommendation 2 and Standards Australia guidelines for reporting. Australians are also at the forefront of the development of evidence-based formulation of evaluative expert opinions. However, there is room for further evolution of the reports and the language used within them, based on the growing psychological and social sciences research undertaken in the field of forensic studies. Ongoing research, in conjunction with efforts undertaken to enhance communication skills of forensic scientists, can assist scientists in designing report templates and selecting report terminology and related expert testimony that can be better understood by non-scientists. Continued attention to the form and language of reports can be expected to contribute to increased trustworthiness and effectiveness of forensic science.

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8

A Step towards Increased Understanding by Non-Scientists of Expert Reports: Recommendations for Readability

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Abstract

Communication about forensic science to non-scientists is a key aspect of the role of forensic scientists – and one that poses significant challenges. Police, lawyers, and judges read expert reports written by forensic scientists, and jurors usually have the content of such reports explained to them in court. Readability can be defined as the ease with which something can be read as a function of the way it is written. This paper draws on past studies of the readability of Australian expert reports of DNA analysis and forensic comparison of glass, and conclusions written as part of an international proficiency test of forensic comparison of glass. The purpose of the paper is twofold: (1) to alert scientists to the most common readability issues identified in the studies; and (2) to suggest solutions to these readability issues drawn from theory and past research. The suggested solutions may be helpful to case-reporting scientists in affirming their current practices or in modifying those practices to enhance the readability of their expert reports for non-scientist report readers.

A Step towards Increased Understanding by Non-Scientists of Expert Reports: Recommendations for Readability

One of the central challenges faced by forensic scientists is determining how best to communicate their findings and expert opinions to non-scientists, including police, lawyers, judges, and jurors, in the criminal justice system. Due to the complexity of the science and the gravity associated with using forensic science to make decisions, clear communication is important. Yet non-scientists face a number of potential barriers to understanding science, including the appropriateness of the level at which it is presented to them and their own scientific literacy. A recent survey revealed widespread agreement about the importance of being educated in science, but found gaps in basic scientific knowledge amongst Australian adults (Wyatt & Stolper, 2013). However, demonstrating that scientific literacy is an issue of worldwide significance, international comparisons suggested that scientific literacy amongst Australian students is higher than the average for OECD countries (Thomson & De Bortoli, 2008).

A number of previous studies have focussed on verbal communication in the courtroom from scientists to jurors, and in particular have considered the wording of expert opinion or evaluative expression (McQuiston-Surrett & Saks, 2009; Smith, Bull, & Holliday, 2011; Martire, Kemp, Watkins, Sayle, & Newell, 2013). Whilst this work is very important, other aspects of the communication may have been overlooked. This paper explicitly considers written reports that are potentially read by police, lawyers, and judges and explained in court to jurors. In many cases, the formal written communication of results may not be supplemented by other communication. For instance, it seems that although face-to-face discussions between police investigators and forensic scientists in the form of case conferences are common for serious crimes such as murder, they are less common for sexual assault and such meetings are not often held for high-volume crimes, such as burglaries (Kelty, Julian, & Ross, 2013). Thus, it is important that readers can understand the formal written communication of scientific results and expert opinions. Because of this, the readability of such written communication is important. Readability can be defined as the ease of reading due to the way in which something is written (Klare, 1963); it is viewed as a pre-requisite to comprehensibility (Badarudeen & Sabharwal, 2010).

A series of three studies was conducted in 2012-3 to explore the readability of expert reports written by forensic scientists (Howes, Kirkbride, Kelty, Julian, & Kemp, 2013, 2014; Howes, Julian, Kelty, Kemp, & Kirkbride, 2014). The first of the studies examined the readability of conclusions written by scientists as part of an international proficiency test (run by Collaborative Testing Services [CTS] in 2011) on the forensic comparison of glass. The second and third studies examined the readability of reports in their entirety from Australian jurisdictions on forensic comparison of glass and DNA analysis. Laboratory directors agreed to participate in the research by providing samples of reports. Samples of reports of forensic comparison of glass and of DNA analysis were supplied by forensic laboratories (in seven and six jurisdictions respectively of the eight Australian jurisdictions). The written reports provided included both summary reports for police investigators, and expert reports or statements for court. Although police investigators may also receive very brief information via a forensic register, such results are not reports per se and thus are not considered here.

Note that in some Australian jurisdictions, a *statement* refers to an attachment to an expert report outlining scientist's specialised knowledge and experience, while the *expert report* is a report, written in a scientific style, provided to the courts. In other Australian jurisdictions, a *statement* or *expert certificate* refers to the expert report, written in a legal style. Whether the reports were in legal or scientific styles, they shared some common features that would increase reading difficulty for non-scientist readers. Each of the three studies on the readability of expert reports and conclusions has been reported in detail previously (Howes et al., 2013; Howes, Kirkbride et al., 2014; Howes, Julian, et al. 2014). This paper draws predominantly from the two studies of Australian reports. This paper does not propose to address issues of scientific validity or reliability, nor the extent to which scientific findings may be probative or otherwise. The paper proceeds on the assumption that the forensic science to be reported by the expert meets both the relevant scientific standards and legal criteria for admissibility to court. The purpose of the paper is to outline the features common to expert reports that may present difficulties for non-scientist readers and to share potential solutions to those difficulties drawn from theory and past research on readability. It is hoped that scientists will find some of these suggestions useful in affirming their current practices and in modifying those practices to further enhance readability.

Measurement of Readability

Readability has been operationalised in a number of ways. Often readability has been measured using surface features of texts, such as the number of sentences per paragraph, the number of words per sentence, and the number of letters per word (Benjamin, 2012). Similar quantitative measures of the surface features of lists and tables also exist (Mosenthal & Kirsch, 1998). Such measures can provide a rough guide useful for gauging the level of reading difficulty. However, a more holistic way to examine readability is by undertaking a content analysis. Content analysis is a commonly-used technique for examining trends in communication (Berelson, 1952). It involves coding features of the texts observed through multiple readings of them. The features coded tend to include one or more of the categories of: the content of the written material and its sequence, the language used, and the format or layout of the written material (Howes, Kirkbride et al., 2014). Each of these three categories can include some consideration of intended readers of the texts, such as the readers' background knowledge of content or assumed familiarity with the language of the text.

In the three studies assessing the readability of expert conclusions and reports, content analysis was used. Different types of content analyses are possible (Sproule, 2010), and the three that were used in these readability studies were conceptual, relational, and directed content analysis. In *conceptual* content analysis, we examined what concepts (or sections) were present in the expert conclusions and reports and identified the specific report types (by discipline, jurisdiction, and intended audience) that contained each concept or section of interest. In *relational* content analysis, we considered the order in which sections appeared in relation to each other and coded them to determine whether similar patterns were present in reports of different jurisdictions. For example, "notes on interpretation" were located before, within, or after the section on interpretation of results. In *directed* content analysis, we drew items from theory or past research and examined the text to describe them or record their presence or absence. For example, reports were examined for the presence of tables and coded (yes/no). When tables were present, their difficulty was assessed and format described. For an item such as paragraph style, more descriptive codes were given (e.g., indented, numbered sequentially throughout document; or not indented, numbered according to section etc.; Howes, Julian et al., 2014).

In the three studies, to ensure a holistic approach to the measurement of readability, quantitative approaches to readability were included as part of the directed content analysis. A full list of items analysed in reports of DNA analysis is presented in Table 1.

Table 1

Categories, Subcategories, and Items Coded and Described in the Assessment of Readability of Expert Reports

		Guide for observations
Category	Subcategories	Items coded for presence and/or described
Content and sequence	Reader orientation	Summary, purpose of report/examinations, nature of case, case context
	Meta-discourse	Case reference numbers, information about use of the report, contact details, accreditation details, signatures, dates, relevant legal acts, relevant scientific protocols
	Main concepts and sequence	Specialised knowledge of scientist, item list, item custody (and dispatch) information, methods of analysis/analytical techniques, results, notes on interpretation/discussion, conclusion/s, references, glossary, other appendix
	Coherence (links and flow)	Links or logical flow between sections, old information before new (can also be observed at sentence level with proposition overlap)
	Dependence of text on appendix	Glossary, other appendix, appendix mentioned in body of report
	Elaboration of important content	References, limitations of techniques used, background information provided, case relevant information, database information, notes on interpretation, separate results and conclusions
Language	Tone of writing	Formality, passive or active voice, use of first person, different tone in different parts of report
	Technicality of vocabulary	In-text definitions, glossary provided, abbreviations or acronyms expanded
	*Readability statistics	Number of sentences per paragraph, number of words per sentence, proportion of sentences in passive voice; Flesch-Kincaid grade level; Flesch Reading Ease
	*Lexical density	Number of content words per clause; number of content words as a proportion of total words
	Communicating uncertainty	Use of expected population frequency, random match probability, likelihood ratio, verbal equivalent of likelihood ratio
Format	Length of reports	Number of pages
	Information chunking	Use of paragraphs (numbered, indented, number of sentences per paragraph) Use of headings and subheadings (concise headings in lay terms, consistent headings used)
	Fonts	Consistent use of fonts, footed font used, at least 12 point font, use of bold for headings and subheadings (not all upper case letters or italics)
	White space	Line spacing, margin size, headers and footers, visible gridlines in lists and tables
	*PMose/IKirsch document readability	Structure and density of lists and tables

Note. The categories and items were derived from theory and past research about readability (see Howes, Kirkbride et al., 2014), from documents informing the contents of expert reports, and from items observed in the expert reports. Items marked with an asterisk* are quantitative measures of readability. Reprinted from *Forensic Science International, 237,* Howes LM, Julian R, Kelty SF, Kemp N, Kirkbride KP. The readability of expert reports for non-scientist report-users: Reports of DNA analysis, pp. 7-18, © 2014, with permission from Elsevier.

The list examined for glass analysis was similar. It should be noted that the criteria examined in conclusions of proficiency tests did not include the category of format (document style) because format was not applicable to proficiency test responses – they were all presented as single paragraphs.

Common Readability Issues and Their Solutions

In this section, features of reports that would hinder readability are presented by category (content and sequence, language, format) with possible solutions to addressing them. It remains to develop and test the use of reports modified for readability in the criminal justice system. However, previously in studies in different fields, such as in patient education, modifications to enhance readability have been demonstrated to improve reader comprehension (Hirsh, Clerehan, Staples, Osborne, & Buchbinder, 2009; Feufel, Schneider, & Berkel, 2010). It also remains to seek readers' and writers' input on expert reports, and a study regarding practitioners' experiences and perceptions of the communication of forensic science in the criminal justice system is currently underway.

It is important to emphasise that the reports of all jurisdictions contained some of the features identified below that would be helpful to readers. In addition, not all of the issues discussed below applied equally to the reports of all jurisdictions. However, each of these issues applied to the reports of a number of jurisdictions. Using the list of issues and solutions presented here, scientists can determine aspects of readability that their reports are currently meeting and those that could be modified to enhance readability. These solutions to readability issues are intended to be applicable to reports regardless of whether they are written in legal or scientific style.

Content and Sequence

The main readability issues with content and sequence were that many of the reports seemed to be missing some crucial information about instructions for use of the report, analytical techniques, or limitations and assumptions. In some cases the information was provided but not in the sequence most logical from the reader's point of view. It is acknowledged that expert reports are influenced by existing scientific and laboratory conventions as well as legal requirements. However, Found and Edmond (2012) recently provided guidelines on the types of sections and content within them that would be helpful in expert reports. If reviewing reports for readability, checking content using the guidelines provided by Found and Edmond is recommended. Sections suggested by Found and Edmond but not often included in reports of most jurisdictions were an executive summary, details of the request made for examinations, and an outline of the case contextual information received by scientists (Howes, Martire, & Kelty, 2014).

Include all relevant steps. Whilst it is not necessary to provide minute detail of all steps undertaken in the process of receiving items, examining them, obtaining results, and forming opinions, enough information about each part of the process should be provided to help the non-scientist to follow the scientist's logic. The steps should be in a logical order where simple proceeds to complex information, old or known information precedes new or unknown information (from the reader's perspective; Graves & Graves, 2003; Britton & Gülgöz, 1991). Although it is typical in some scientific journals for the method section to be placed as an appendix, this practice is unlikely to be familiar to non-scientist readers. Information that lets readers know the basic methodological or analytical steps followed and whether or not any variations to routine were necessary in the case at hand, might be helpful in providing readers with a picture of the case from the scientist's perspective. Such a section need only be very brief but should not be omitted. If the use of appendices is justifiable from a laboratory perspective (e.g., as a time-saving measure), then the method or analytical techniques section should still be retained in the body of the report, and the reader explicitly referred to the appendix for more information.

Write a comprehensive summary. For some readers, the conclusion of an expert report may be the only part of it that is read closely (Rothwell, 2010). Therefore, where possible, it would be helpful if a comprehensive summary, representing the contents of the report overall, were to be provided (Howes et al., 2013). Such a summary would fulfil a role similar to that of an executive summary of a report in government or industry, or an abstract for a scientific journal article. (However, see the section on language.) The summary would ideally contain a statement about the purpose of the report, the nature of items received, the method/s used, the results, and the interpretation of those results in light of the assumptions and limitations of that method. The inclusion of a comprehensive summary is a far more important issue than whether it is located at the end of the expert report as a conclusion, or at the beginning as an executive summary.

Refer to limitations and assumptions. The limitations of analytical techniques and the assumptions that must be made to use them may be obvious to scientists of the same specialisation, but are not obvious to non-scientists and cannot be considered assumed knowledge (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). The limitations and assumptions that pertain to the report should be mentioned in the sections in which they are relevant. In particular, the interpretation of results takes into account various factors that non-scientists would not be aware of and not know to consider. If limitations and how they are accounted for are not explicitly mentioned in expert reports, the non-scientists who read the reports cannot be expected to be aware of them. This may have potential implications in non-scientists' understanding of the weight of the evidence and in the types of questions asked of scientists about the scientific evidence. Although the issue of communicating the strength of evidence is not yet resolved (i.e., whether it should be a verbal or a numerical expression or both and how specifically it should be expressed;

Howes, Martire et al., 2014), presenting the limitations and assumptions goes part of the way to explaining the complexity of the science and the type of room for uncertainty.

Provide information about the report itself. The reports of some jurisdictions contained helpful information about the use of the report (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). Helpful information included the purpose of the report (e.g., to report a comparison between x and y in relation to a burglary), intended use of the report (e.g., whether or not the report was suitable for court purposes, the fact that the report could not be reproduced except in full, the NATA accreditation status of the laboratory). Limitations of the report itself were also observed in some reports (e.g., if further information becomes available, an updated report will be provided). Further information was also offered (e.g., full details of statistical calculations, and who to contact to obtain further information). A statement about impartiality and how defence could obtain further information was provided on some reports. If certain terms are defined in an appended glossary, it should be mentioned early in the report. Information about the report could be provided in a specific section (e.g., "Use of this report"), or as needed throughout the report.

Evaluate the need for appendices. It is probably convenient for the writer to use appendices for parts of the report that are generic to all reports (such as glossaries of terms) or that differ by reporting scientist (such as statements of relevant qualifications and experience to the role of expert). However, it is important to note that it is not a requirement of expert reports that they contain appendices. Not all reports of all jurisdictions do so (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). Although common in science, non-scientists may find it awkward to flick back and forth through the document to locate appended information if it seems to be out of sequence (e.g. method placed in appendix). It may be possible to integrate much of the recurring information into the main body of the report. In particular, for example, if a conclusions scale is used to provide an indication of the degree of support for a proposition (e.g., extremely strong, very strong, strong, moderately strong, moderate, limited, inconclusive), then it seems that providing the scale upfront to the reader and explaining a little about the basis for its use would be helpful (e.g., to give a verbal indication of the strength of statistical interpretations). If terms to be defined are used multiple times throughout the report, the use of a glossary may be warranted. One option may be to place a glossary in a section early in the report. If an appended glossary is deemed necessary, it seems that it should be responsive to the report in question, rather than providing a list of every scientific term that may be needed in reports written in that sub-discipline. The same logic can be applied to analytical techniques – if a technique was not used in a particular case, it seems odd to include it in an appendix, unless the reason why it was not used is somehow relevant to the case at hand.

Language

The main issues with language from a reader's perspective were the difficulty of visualising what items were being discussed, the average length of sentences, and the density of content terms in them. Many reports contained sentences that were written with highly specialised terms that were not always defined (Howes et al., 2013; Howes, Kirkbride, et al., 2014; Howes, Julian et al., 2014). Part of the difficulty with language stemmed from the fact that scientific language is specialised and differs from lay language (Halliday, 1993).

Use descriptive terms for items. Although numbers are assigned to items submitted for scientific examination, these numbers are not memorable to the reader. Furthermore, items may be assigned different numbers by police and by forensic laboratory staff in at least some jurisdictions. For the purposes of helping the reader to follow the report, the use of descriptive terms (e.g., “the blue jeans”) for items is recommended. Descriptive terms allow readers to form mental images of the items (Britton & Gülgöz, 1991). For the sake of accuracy, the item number should be provided in parentheses after the descriptive term. If it is done the other way around, it prioritises the number and this is less likely to be helpful to the reader. If items are only identified by numbers, the reader must flip back to the list of items to establish which one is being discussed (Howes, Kirkbride et al., 2014).

Use readability statistics as a diagnostic tool. Readability statistics can provide an idea of the difficulty level of a report (Howes et al., 2013). Microsoft Word provides this information (via Review > Spelling and Grammar > Show Readability Statistics). The statistics appear after completion of the spelling and grammar check. These statistics include the Flesch-Kincaid grade level, a measure based on number of words per sentence and other surface features of text, which indicates the number of years of education that someone would need in order to be able to read and comprehend the text to an adequate extent. Most readers of expert reports would have completed education in science to the mandatory level at high school (up to Year 10, because science is not a pre-requisite school subject for entry into policing or law degrees). Whilst many readers have undoubtedly attended university, it is important to bear in mind that most are unlikely to hold a degree in science. The Flesch-Kincaid grade level may tend to overestimate abilities at each level, so lower levels are preferred for a broad readership (Ley & Florio, 1996). For expert reports of forensic science, text written at a grade level of between 7 and 9 would be ideal. Scores above Grade 12 level indicate that the text is written at a level more appropriate for scientist peers. The Flesch Reading Ease score is another readability statistic that is related to the Flesch-Kincaid grade level and is included in the readability statistics offered by Microsoft Word. It provides a score from 0 to 100, where 0 is *extremely difficult*, 60-70 is *standard*, and 100 is *very easy* to read (Flesch, 1948).

As an example, the paragraph above this one has a Flesch-Kincaid grade level of 13.7. This indicates that it is written at a level that would require at least an undergraduate university education to read and understand it. The Flesch Reading Ease score of 38.5 suggests that it is within the range of text that would be considered *difficult*. By contrast, this paragraph obtained a grade level of 9.8. The reading ease score was 50.6. This means it could be considered between *standard* and *fairly difficult* to read.

Another useful score provided in the Microsoft Word Readability Statistics is the proportion of sentences using the active voice ("I compared the samples.") versus the passive voice (e.g., "Samples were compared."). The active voice is easier for readers to understand because they can determine agency more easily than when the passive voice is used (Roland, 2009). For example, in the sentence "Samples were compared." it is not made clear who compared them. Forensic scientists have been asked to distinguish clearly between results and opinion (Keane, 2011). To do this, the first person is used in some jurisdictions (e.g., "in my opinion,…") and this is an effective way to make clear to readers where the interpretive component of expert opinion begins.

However, it is important to note that because readability statistics are calculated using surface features of text, they should only be used to obtain a rough idea of its difficulty level and not to re-write a document (Klare, 1981). The reason for this is that due to the way the scores are calculated, it is entirely possible for a nonsensical text to obtain, for example, Flesch-Kincaid Grade 8 and high Flesch Reading Ease scores (Benjamin, 2012). The types of modifications needed to reduce the grade score effectively are presented below.

Define specialist terms. Where it is possible to reduce the number of specialist terms used in expert reports, without compromising on scientific accuracy, it would be advisable to do so. However, when referring to a scientific process or apparatus in a report, it is often preferable to use scientific terms because they provide a more precise term for what is being described. Furthermore, it is not always possible simply to “translate” scientific terms into lay language as direct equivalents do not always exist (Peters, 2008). For example, a scientific apparatus, such as a glass refractive index measurement system, or GRIM 3, used to measure the refractive index of glass, should be described as such. (The acronym should also be expanded when first used in the document). For scientific terms familiar to non-scientists, it does not seem ideal to use a more lay term. For example, DNA is a term that is commonly known in the lay discourse and changing it is more likely to create confusion amongst readers, especially those for whom it is more familiar.

However, to ensure that readers do not have a misconception about the meaning of familiar scientific terms or common terms used with scientific meaning, terms should first be defined by the scientist in the report. For non-scientist readers, in-text definitions are essential at the first use of the scientific terms and general terms used with specialist meanings. In addition, because not all readers of expert reports would read them sequentially, if specialist terms used multiple times and are not defined at each use but rather in a glossary, the defined terms should be identified in some way (e.g., highlighted in bold) so that readers know to refer to the glossary (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). Terms defined in a glossary should be defined in such a way that the definition is as self-contained as possible, and readers need not look up other specialist terms used in the definition. Thus, it may be helpful to aim to define terms in a way that would be suitable for a high school (Year 7-9) science text book, bearing in mind that if specialist terms are used within definitions, these should also be explained.

Keep sentence length in check. One of the easiest ways to reduce the grade level is to break down complex sentences into two or three sentences (Howes et al., 2013). This is easy to do for compound sentences that contain “and” and complex sentences that contain "because", "so", or "however". One way to help ensure that the first of the sentences is not taken out of context on its own without the follow-up sentences is to use linking words, such as "therefore" or "this means" to start those follow-up sentences.

Avoid overloading sentences with content. Another way to decrease the difficulty of text at the sentence level may seem counter-intuitive because it makes sentences longer by adding prepositions (and punctuation). A feature of scientific writing, which makes it dense with content, is to use many nouns in succession (Fang, 2005; Halliday, 1993), rather than using adjectives, adverbs, and prepositions as is done in lay language. In the reports examined, often sentences contained few words with a grammatical function (such as prepositions), relative to the words with content. This means that *lexical density* (content) is high (Halliday, 1993) for each clause (distinct part of a sentence containing its own verb group), adding to readers' processing time. When prepositions and punctuation are added to sentences, although sentences become longer, they are simultaneously made clearer to non-scientist readers. For example, an expression such as "Glass fragments recovered from the [item]…" may be clearer to a non-scientist when expressed as "Fragments of glass, which were found on the [item], …". Similarly, an expression such as "microscopically examined" may be clearer in meaning to a non-scientist when expressed as "examined using a microscope".

Take care with complexity of tables. Some studies have indicated that greater complexity of tables is associated with decreased reading ease. Tables become more complex with every row or column added and with every use of notes located below the table or in other parts of the document (Howes, Julian et al., 2014). Thus, there may be instances where it would be better to use more than one table, than to use a single but highly complex table. This may be relevant when reporting results for items from multiple cases in a single report. Similarly, when results of a number of items with multiple subsamples are reported, there may be times when a table for a single item and all its subsamples is warranted. The table could be followed by a paragraph to summarise and discuss the results outlined in it (Howes, Julian et al., 2014) particularly when the results pertain to an item overall or to items retrieved in relation to a particular person or location. The reason that a paragraph summary would be helpful is because it is easier for readers to *locate* than to *interpret* information presented in table form (Mosenthal & Kirsch, 1998).

Format

The main issues identified with report format were that reports often appeared cluttered due to both the presence of headers and footers and the use of single line spacing (Howes, Kirkbride et al., 2014; Howes, Julian et al., 2014). In addition, the information contained in headers and footers was often in an extremely small font. Not all reports contained headings and subheadings, and of the reports that did, some headings were fairly technical in nature. Headings were not always used on each column of a table or on each page of a multi-paged table.

Choose easy-to-read font type and size. The selection of font size and type is worth considering. For reading on screen, it has been suggested that a sans serif font, such as Arial, is clearer than a serif font. Conversely, for reading on paper, a serif font such as Times New Roman is considered optimal as the feet on the letters help to guide the eye across the line (Doak, Doak, & Root, 1996). However, it has been noted that even on paper, some readers may prefer sans serif fonts, such as Arial, due to their larger appearance (Shrank, Avorn, Rolon, & Shekelle, 2007). Ideally, the size of the font should be at least 12-points for most readers (11-points for Arial); bearing in mind that some readers would prefer an even larger font size.

Retain word shape. Although highlighting single words in capitals or italics is not problematic, doing so for entire headings or for entire sentences may decrease the ease with which readers can process the text. Adult readers (who are fairly skilled at reading) do not focus on each individual letter while reading familiar words, but tend to use cues such as the first and last letters of words, the overall shape of the word, and the sentence context. The shape of the word is given by the number of letters it contains and the upward or downward stems on letters. For this reason, it is harder to read words when their shape is unclear, such as when portions of text are italicised or in block capital letters (Doak et al., 1996). Similarly, when the text is justified so that the right edge lines up neatly, the spacing between letters and words is artificially increased or decreased and is no longer uniform. This non-uniform spacing of letters and words means that the eye cannot predict the spacing between letters and words, increasing reading difficulty. Thus, it is suggested that reports be presented with text aligned to the left-hand margin only.

Use headings and subheadings. For many readers of expert reports, the scientist's expert opinion is of greatest interest (Allnut & Chaplow, 2000). Many readers are unlikely to read the report sequentially from start to finish. Thus, the use of headings and subheadings is important to enable the reader to navigate their way around the document and locate the information that they seek (Burrough-Boenisch, 1999). Headings should ideally be brief, in lay terms or at least not overly technical, and stand out clearly (e.g., with bold font). Similarly, for multi-paged tables, headings should appear at the top of each page. There should be some indication that the table is continued (whether by a statement at the bottom of the page "continued on next page" and on top of the page "continued from previous page" or indicated by a numbering system in the left-hand column of the table).

Include white space. The inclusion of white space on a page is important, so as not to overwhelm readers with text (Doak et al., 1996). One of the easiest ways to introduce white space is to increase the line spacing from 1.0 (commonly used in the reports of many jurisdictions) to 1.5 or 2.0. Another way to increase white space is to increase the width of margins around the text. While some jurisdictions had narrow margins, others had wide margins. However, these margins were often cluttered with information in headers and footers and sometimes ruled off by lines. A solution offered in one jurisdiction's reports, if it was deemed necessary to use headers and footers, was to use wide margins and grey font for that information, lessening its impact in terms of clutter. Another way to increase white space is to reduce the number of grid lines shown in tables. If it seems that removing lines could lead to confusion, making them finer is an alternative that would be helpful to readers.

Provide visual information. If relevant, visual information in the form of figures, diagrams, and photographs, would help to communicate with readers (Doak et al., 1996). Whilst it may not be necessary or desirable to include images in every report, there may be times when a complex idea is explained more clearly through the use of a diagram. For example, in reports of forensic analysis of glass, where it is of particular relevance, perhaps the idea of "matching and non-matching groups of glass" for an item (or series of items) could be depicted in a figure. For DNA analysis, a diagram could help to explain the idea of sampling and the sampling rationale. An alternative would be to include photographs if it made sense to do so, perhaps with arrows to indicate from where samples were taken. It should be emphasised that it is not suggested that this should necessarily apply to every expert report, but that if it made sense to do so given the nature of the case or the items, visual information would be helpful to readers.

Conclusion

Scientists do not always have the opportunity to discuss the contents of their expert reports with readers. Therefore, expert reports must be capable of functioning as standalone documents. The reports need to provide enough information to alert readers to some of the issues of which experts are aware, such as the limitations inherent in the techniques used and assumptions made in the interpretations. Critically, readers should be advised of how they can access further information if required. Including such content and modifying the format and language to make reports more readable for non-scientists may assist in facilitating understanding of the forensic science by non-scientists. The issues and simple solutions for readability described in this paper were drawn from theory and past research. Using these suggestions, it is hoped that the gap between the meaning intended by scientists and the meaning understood by non-scientists can be reduced. In doing so, scientists can be more confident that their reports will be understood adequately by those who are tasked with using them to make important decisions in the criminal justice system.

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Part 4

Practitioners’ Perspectives on the Communication

9

"Sometimes I Give Up on the Report and Ring the Scientist": Bridging the Gap between What Forensic Scientists Write and What Police Investigators Read

This chapter has been published as follows:

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Abstract

Despite increased use of forensic science in police investigations, relatively few studies have examined how well forensic science is communicated to police investigators. This study explored practitioners' perceptions of the effectiveness of such communication in Australian jurisdictions. Sixty-five participants, consisting of police (investigators, *n* = 28; and liaison officers, *n* = 10) and case-reporting scientists (forensic biologists, *n* = 16; and trace evidence examiners, *n* = 11) participated in semi-structured interviews. Interview transcripts were analysed thematically and the communication process from crime scene to court was examined in light of a conceptual model of forensic science communication. One-way communication was appropriate throughout the process for most routine cases. However, in other cases, two-way communication was important. Specifically, participants viewed discussion as necessary for police investigators, to facilitate on-the-job learning about forensic science generally, and to clarify aspects of forensic science in particular cases, especially serious cases, or when the science was complex, unfamiliar to investigators, or relied upon to advance the case. In addition, participants considered discussion helpful for forensic scientists in understanding the information needs of police investigators, and essential at the managerial level to ensure that operational priorities relating to forensic science were aligned. The implications include the need for further refinement of written reports and online systems, and more explicit recognition of the value of discussion as one component of effective communication about forensic science, both to enhance professional development, and to prevent information loss.

“Sometimes I Give Up on the Report and Ring the Scientist”: Bridging the Gap between What Forensic Scientists Write and What Police Investigators Read

Technological advances in recent years have led to increased capability of, and demand for, forensic science (Peterson, 2015). Clear communication about forensic science, and adequate understanding of it by non-scientists, are important to the trustworthiness of the criminal justice system. A body of research has considered the communication of expert evidence in the criminal justice system, with studies focussing on the understanding of such evidence by jurors (e.g., Goodman-Delahunty & Hewson, 2010; Martire, Kemp, Watkins, Sayle, & Newell, 2013; Smith, Bull, & Holliday, 2011), and by lawyers’ and judges’ (e.g., Cashman & Henning, 2012; de Keijser & Elffers, 2011). Police investigators make decisions that contribute to whether or not cases progress to the next stage of the criminal justice process (Strom & Hickman, 2015); yet comparatively little research has explored the effectiveness of the communication about forensic science to police investigators.

Two issues in the communication about forensic science to non-scientists, including police investigators, are the specialised nature of scientific concepts and language, and the often limited background knowledge of science amongst non-scientists. Although science is not a pre-requisite subject for entry into a career in policing, police investigators receive expert reports, and many such reports of forensic biology (DNA) and trace chemistry (glass) were found to be written at a level of scientific expertise suitable for other experts (Howes, Julian, Kelty, Kemp, & Kirkbride, 2014; Howes, Kirkbride, Kelty, Julian, & Kemp, 2013, 2014). A number of recommendations have been made to address some of the difficulties inherent in these reports (National Academy of Sciences [NAS], 2009; Found & Edmond; 2012; Howes, 2015a; Siegal, King, & Reed, 2013). However, scientific discourse can be seen to encompass ways of thinking, and direct translation into lay language is not always possible (Peters, 2008), rendering the communication of forensic scientific results and expert opinions an ongoing challenge.

Related to limited background education in science, low forensic awareness amongst police officers throughout the process from crime scene to court has been identified as an issue with potential implications for criminal justice outcomes (Julian, Kelty, & Robertson, 2012; Vincent, 2010). Police investigators and organisations need the results of testing to be communicated quickly and efficiently, so that forensic science can be used to enhance investigative decision making (Schroeder & White, 2009; Strom & Hickman, 2010). Yet in some instances, delays in the forensic identification process from crime scene attendance to arrest were introduced by police officers rather than by forensic scientists. For example, a US study found that police investigators did not always submit DNA samples to laboratories when a suspect had not been identified, even though an association between a profile obtained from a sample from the crime scene and one on the database might offer an avenue of enquiry in the investigation (Strom & Hickman, 2010). In a similar vein, an Australian study documented that the longest stage in the forensic process for DNA evidence, was from the identification stage to the arrest stage (Brown, Ross, & Attewell, 2014). The researchers attributed the time lag at this stage of the process to low forensic awareness about compliance with legislation regarding the collection of DNA samples.

To address the shortfall in police officers' levels of forensic awareness, in addition to further training, increased communication between forensic scientists and police investigators has been recommended. For example, to reduce instances of non-submission of items that could potentially add value to investigations, Strom and Hickman (2010) identified the need for clear and up-to-date communication to police investigators of laboratory item acceptance policies. Furthermore, to identify issues, such as potential contamination, a need exists for regular communication between practitioners in policing organisations, laboratories, and others in the criminal justice system (Strom & Hickman, 2015; Vincent, 2010). Crucial to such communication is recognition by practitioners in the criminal justice system of their roles as one part of the larger process, so that instead of working in isolated justice silos, concerns that are identified by practitioners at one stage of the process can be communicated to those at other stages (Kelty, Julian, & Ross, 2013; Vincent, 2010).

However, the call for increased communication between forensic scientists and police investigators is not entirely straightforward. Forensic scientists have a legal obligation to remain impartial, and the NAS Report (2009) recommended that forensic scientific laboratories maintain independence or autonomy from policing organisations. In recent years, concerns have been raised about the potential for case information to affect experts' interpretation of scientific findings through contextual bias (e.g., Dror & Hampikian, 2011; Kassin, Dror, & Kukucka, 2013). The extent to which policing organisations and forensic scientific laboratories should have a client and service provider relationship as opposed to a partnership or close collaboration is unclear (Robertson, 2012; Esseiva et al., 2007). This lack of congruity makes meeting communication challenges a complex endeavour in the current forensic science and policing context.

Approaches to the Communication of Forensic Science

Science communication has been described as conforming to deficit, dialogue, and participation approaches (Bucchi, 2008). A deficit approach assumes that expert knowledge can be transferred from a scientist to a non-scientist and is associated with one-way communication. By contrast, two-way communication includes the dialogue approach, which recognises that public discussion and debate about science is not solely the terrain of scientists, and the participation approach, in which non-scientists are actively engaged in decisions about science (Bucchi, 2008).

The communication of forensic science in the criminal justice system has been described, primarily, in terms of a deficit approach (Howes, 2015b). It has been argued that on a continuum of deference to education about scientific expert opinion, police investigators can generally defer to expert opinion to enhance investigations (Roberts, 2002). A conceptual model of the communication of forensic science, based on Shannon and Weaver's (1949) transmission model can be seen in Figure 1. The model depicts a linear, one-way communication process in which forensic scientists are the senders of messages of expert opinion, formally as written reports (or expert testimony) to police investigators (as well as lawyers, judges, and jurors), who are the receivers of those messages.

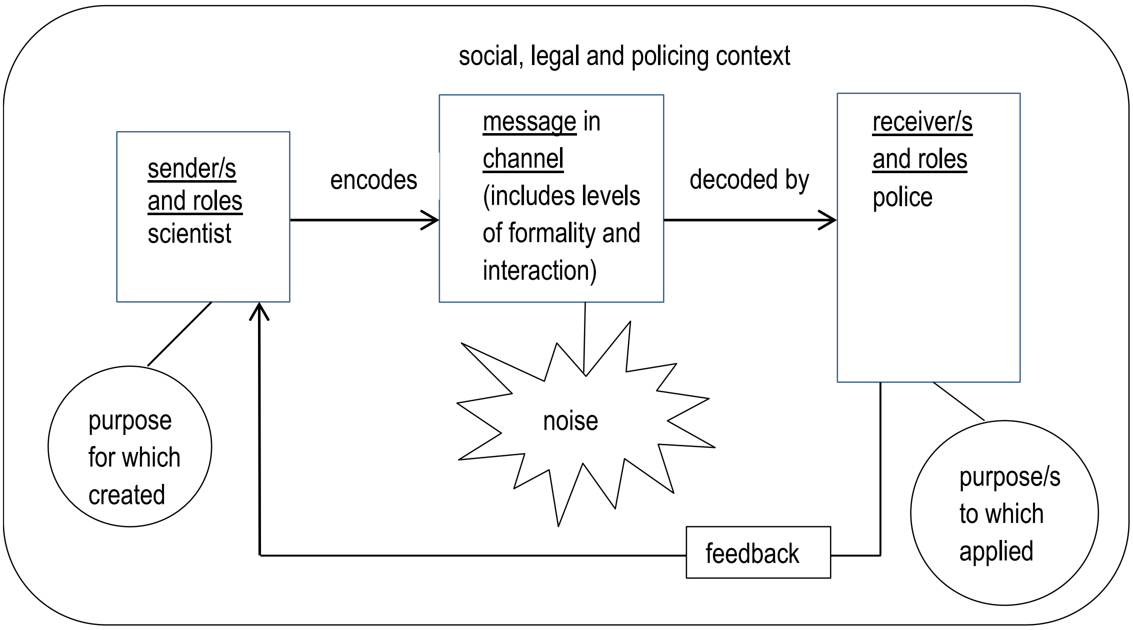

Figure 1. Conceptual model of the communication of forensic science.

However, in any scientific field, it is likely that a blend of approaches is in use, even when a deficit approach is dominant (Bucchi, 2008). Despite the restrictions on communication inherent in the criminal justice system, instances of dialogue and participation approaches are evident (Howes, 2015b). For example, one exception identified in past research is the use of case conferences during investigations of major crime, such as homicide. Case conferences facilitate shared decision-making amongst police investigators, crime scene examiners, and forensic scientists, regarding which items should be prioritised for examination in light of the case circumstances (Kelty et al., 2013). The participants in such case conferences can be viewed as communication partners who negotiate shared meaning in a two-way, contextual process, consistent with constructivist views (Campos, 2007; Howes, 2015b).

The Current Study

Forensic scientific results and expert opinions are routinely communicated via written reports to police investigators. Although case conferences are held for major crime, it is unclear whether for other cases police investigators perceive a need for, and have access to, opportunities for two-way communication about forensic science in the course of their investigations. The aims of this exploratory study were threefold: (1) to ascertain trends in current communication practices based on the experiences of forensic scientists, liaison officers, and police investigators in Australian jurisdictions; (2) to gain insight into their perceptions of the effectiveness of current communication practices; and (3) to identify aspects of the communication that could be improved and propose directions for refinement, in light of the approaches to science communication and the contemporary context of policing and forensic science.

Method

Sampling and Procedure

To determine issues in the communication about forensic science that applied across jurisdictions in general, it was desirable to include participants from as many Australian jurisdictions as possible. The goal of sampling was not to obtain a particular number of participants from each jurisdiction. Rather, a purposive sample of participants with relevant experience and expertise was sought (Mason, 2002).

The research committees of seven of the eight Australian police jurisdictions agreed to facilitate the research. Four jurisdictions had forensic biology and chemistry laboratories that were organisationally distinct from policing; support for the research in these jurisdictions was sought from laboratory directors, and three agreed to facilitate the research. Organisations nominated or requested volunteers from a pool of potential participants who had suitable experience. Potential participants received information sheets and consent forms and were contacted via email to negotiate a mutually suitable time for the interview. Interviews lasted between 29 and 75 minutes (M = 48.6 min., SD = 8.4) and were conducted via telephone using a digital voice recorder.

Participants

A total of 65 practitioners participated in the study. Police investigators (n = 28) were primarily detectives, ranked from constable to inspector, from seven jurisdictions. The majority had current experience in major or serious crime investigations; a few had current experience in the investigation of high-volume crime and past secondment to serious crime units. Police liaison officers who had a role in the communication about forensic science to police investigators were included in the study once the importance of their roles became apparent during other interviews. Police liaison officers (n = 10) included both sworn and unsworn police employees from five jurisdictions whose roles ranged from crime scene examination, to item triaging, and results management, along with some high-level managers with oversight of others in these roles. All liaison officers' roles involved communication about forensic science with police investigators and laboratory forensic scientists. Forensic scientists included case-reporting scientists and team leaders who were forensic biologists (n = 16) from seven jurisdictions who specialised in reporting DNA evidence, and forensic chemists (n = 11) from five jurisdictions who specialised in reporting forensic comparison of glass and other sub-disciplines within the chemical trace evidence discipline.

Materials

Semi-structured interview guides were prepared, each containing six key questions. All participants were asked to explain a little about their roles. Police investigators were asked how scientific results were usually communicated to them; what types of communication about forensic science they found particularly helpful and unhelpful; and how they found the written reports specifically. Police liaison officers were asked how information about forensic science was usually communicated to them; and the levels of interaction they had with police investigators and forensic scientists. Forensic scientists were asked about their experience of explaining their findings; what influenced the way that they explained them; and how well they thought that their findings were understood. All participants were asked whether they would suggest any changes to improve the way that the results are understood and used.

Data Analysis

Interviews were transcribed verbatim, with the assistance of two research assistants. Once all interviews were completed, numbers were randomly assigned to transcripts by practitioner group. Participants had the opportunity to view their transcripts and make amendments, if they so wished. Minor changes were made to three transcripts as a result. Interview transcripts were analysed in two stages. In the first stage, the communication process was examined by tabulating the nature of communication by the stages of the process from crime scene to court and the components of the conceptual model of communication of forensic science. In the second stage, transcripts were analysed thematically, following the procedure outlined by Braun and Clark (2006). Transcripts were each read multiple times and qualitative codes were assigned to ideas present in the transcripts. Similar codes were grouped together to form tentative themes. Four main themes resulted: *the need to understand forensic science*; *learning about forensic science through discussion* (incorporates the process of communication from the first stage of analysis); *organisational policies and communication partners*; and *impediments to effective communication*.

The four themes were mapped onto the conceptual model of forensic science communication (see Figure 2). Quotes that best represented the comments made by participants were selected to illustrate themes. Each theme and quote represents the views of a substantial proportion of participants or sub-group of participants, unless otherwise stated to specifically illustrate a contrasting viewpoint.

Results

It is notable that, in general, across jurisdictions, participants from all represented groups were largely satisfied with the communication about forensic science between them and many reported that they had experienced recent improvements in the communication. Police investigators, liaison officers, and forensic scientists demonstrated mutual understanding of some of the complexities faced by practitioners in the other roles, and were respectful in their critiques of current practice. However, they did identify some areas of tension for further improvement or refinement. The four themes are discussed in turn below.

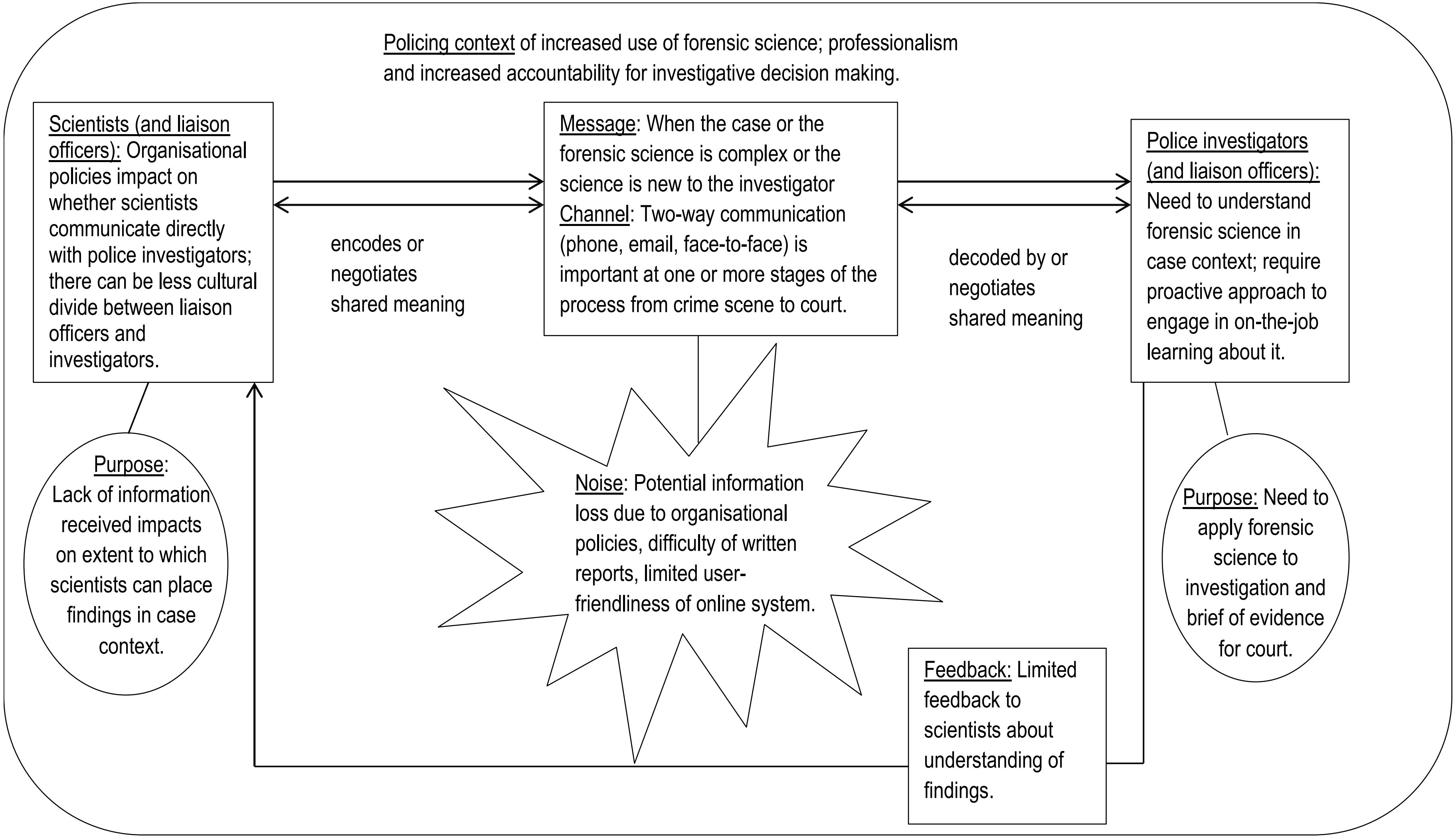

Figure 2. Summary of key themes from interviews mapped onto conceptual model of the communication of forensic science.

1. The Need to Understand Forensic Science

A number of elements were seen to contribute to police investigators’ need to understand forensic science. Police investigators perceived that they needed to understand forensic science because they used it routinely, with its relative importance varying by case:

> In most matters that we do at some point we use the services of different experts in forensic science. We – for most matters, if they go to trial – we require some form of experts depending upon the type of investigation it was, so they’re very important (Police Investigator 5)

To ensure that opportunities to get a positive outcome were maximised for victims, families of victims, and their community, police investigators perceived the need for a global understanding of the case.

> …we’re the intermediaries that have to act upon and understand so we can go further and do something … so that you don’t look like an idiot talking to DPP or in court, you do understand your case thoroughly – and that’s hugely important – and the evidence that you have (Police Investigator 23)

Specifically, police investigators needed to know how to apply forensic scientific findings and expert opinions to their investigations, as a decision-making aid. In the information-gathering phase of an investigation, results assisted in police investigators’ decisions about the next course of action.

> I’m concerned about, I guess, what the exhibit is, what’s been tested and whether there’s an identification or something to, to um be able to conduct further avenues of investigation (Police Investigator 27)

Obtaining the written reports (court statements) was crucial in the lead-up to court, as part of the brief of evidence, because it represented “what scientists commit to and sign off on”. Investigators did not deem it necessary or entirely possible to understand the process of how results were obtained, as this was the province of the experts, who could explain in court if required. An understanding of the strength or weight of the evidence was considered essential along with consideration of the relevance of the association (e.g., was a fingerprint located on the inside or outside of a window? Was the victim's blood on an item belonging to the victim or to the suspect?). This type of understanding of the findings was seen to be essential, to determine whether there existed sufficient corroborating evidence to substantiate an offence, bearing in mind the goal of using the best available evidence to do so.

Depending upon their specific roles, some police investigators reported the need to understand the forensic science relevant to a case to outline it to others, including their investigative team in briefings, and the prosecution (who did not always meet with forensic scientists) through a statement of facts to summarise the brief of evidence and possibly in face-to-face discussion.

> Before the matter's at trial, it's generally left for the investigators to explain that to the prosecution….what the meaning of the report is. (Police Investigator 9)

Thus, an understanding of forensic science was seen as a necessary aspect of an investigator's role, in a contemporary policing context.

2. Learning about Forensic Science through Discussion

The content about forensic science in recruit and detective training courses reportedly consisted of the procedures to follow in the containment and management of a crime scene:

> … we have a couple of hours where we can talk to them about what we do, how we do it, and what precautions they should be taking. (Case-Reporting Biologist 16)

Due to limited opportunities for formal learning, on-the-job learning about forensic science was essential. In one jurisdiction only, the possibility of on-the-job learning from the police intranet was mentioned by participants from all groups.

> There is a specific forensic department website that they can go onto …and within that now is some really, really good guides and it tells you, you know, packaging, special packaging requirements, the actual criteria for getting things in and out of the forensic lab, you know, or rejection – what won't be accepted. (Police Liaison Officer 8)

On the whole, it was discussion that facilitated on-the-job learning about forensic science for police investigators and liaison officers alike.

> You know, we'll say, 'Well, why can't you do this?' and they'll explain exactly why and they do it in, they explain in layman's terms – they do make it easier for us to grasp why. (Police Investigator 23)

Police investigators saw the communication about forensic science to begin at the crime scene, with an opportunity to communicate with crime scene examiners, and proceed through a number of stages (identified in the left-hand column of Table 1), potentially culminating in a trial in court. For routine cases, the communication between police investigators and forensic scientists was generally limited to electronic communication.

> We go onto the system, select that exhibit and create a job for whatever particular section we want to have examine it and um it gets sent to them electronically…. they do their examination and carry out their processes …. and I would just receive the report. (Police Investigator 10)

Although the intricacies of communication protocols differed somewhat by jurisdiction and case type, opportunities to supplement the routine online communication occurred at each stage of the process and allowed on-the-job learning to occur. Table 1 provides examples of the types of information that police investigators reported learning at each point in the process from crime scene to court. The importance of this learning is highlighted by examples of the potential consequences of not engaging in further communication when it was needed, also provided in Table 1.

As the examples in the table suggest, relational, on-the-job learning was important not only for consolidating knowledge of the scope of forensic science and the procedures to follow, but also to more complex thinking about how forensic science could enhance an investigation.

> I actually have to plan and think why am I going to engage this office? What do I want them to find for me? And what evidence do I have that I can give them? It's really a bit of a two-way thing, it's really a bit analytical when you break it down to it but you always walk out of the meeting much smarter and with much more direction –
> I'm all for it! (Police Investigator 11)

Table 1

Examples of Police Investigators' Learning about Forensic Science through Communication and Potential Consequences of a Lack of Necessary Communication

Stage of process	Type of learning about forensic science facilitated through two-way communication	Consequences of a lack of communication
Before analysis: Crime scene	• practical issues (e.g., correct packaging and storage; steps to prevent contamination) • the forensic scientific disciplines that might add value to the investigation in light of items collected and nature of case • crime scene examiners' (CSEs) thought processes at a crime scene (useful to recognise role distinctions and help with thinking broadly about a case)	• value of an item may not be evident to CSEs without some case context – items might be missed with little opportunity to collect them at a later date
Triage of items	• the logic of requesting an examination in relation to the case (accountability for investigative decision making – items could no longer "be forenisc'ed for the sake of it") • types of tests possible, limitations of them, potential for results • the most appropriate sequencing of testing when multiple disciplines were to test an item	• police and scientists may differ in perception of case urgency or priority need • areas on items irrelevant to the case may be swabbed for DNA testing, and a negative result received
Request for examination	• the information needs of scientists from various disciplines for examination of items	
Vetting of items	• further information about criteria for acceptance of examination requests	
After analysis: Receipt of summary of results by police	• the meaning of terms with regard to whether or not an association was found • how to locate and view results on the computer system • the meaning of results in the case context (including the meaning of a negative result)	• if conclusions are misunderstood, flawed investigative decision-making may occur (e.g., wrongly eliminating a suspect), or deciding not to proceed with (a viable) case
Request for statement	• an indication of lag time from request to expected receipt of statement	
Receipt of statement for court	• what the scientist is willing to testify in court and more information about the strength of the association as indicated in the expert's opinion	
Handover of brief of evidence to prosecutor	• whether the prosecutor perceives a need for further testing of items or requires some clarification from scientists (may be communicated via police investigator)	

Note. Examples of the stages of the process, the types of things learned about forensic science, and the potential consequences of not communicating were drawn from interview transcripts.

The use of discussion was related to the complexity of the case. As was found in past research (Kelty et al., 2013), case conferences were used for homicide investigations, which potentially involved hundreds of items for examination. In addition, depending upon the jurisdiction, case conferences were held for investigations of other serious crimes, such as sexual assault, child protection cases, long and protracted investigations of organised crime or fraud, and at the detective's request. Communication via telephone and email supplemented face-to-face discussion for serious crime, and was also used in less serious cases.

Discussion was also used when the forensic science was complex or was of particular importance to a case. Although the police investigators interviewed used different scientific disciplines depending upon their cases, certain disciplines were frequently mentioned as being difficult to understand, sometimes requiring a number of discussions for clarification. These included DNA (especially with mixed profiles), pathology, and toxicology, and reports of a medical nature. By contrast, the reports prepared by forensic scientists traditionally located within policing (e.g., crime scene examination and fingerprinting) were typically seen as more accessible. In general, forensic chemists reported receiving fewer follow-up queries than did forensic biologists. Queries about chemical trace evidence were reportedly received when it was pivotal to a case, indicating that a greater role for the scientific evidence in the investigation also contributed to the need for discussion about it.

> And the investigator did send me an email back saying, 'Oh, do you have anything stronger?' But…. I don't regularly get emails back saying, 'Can you explain this to us, please?' (Case-Reporting Chemist 8)

The need for discussion related to police investigators' experience in using the forensic scientific discipline in previous cases, and applied both to police investigators who were new to detective work and to experienced detectives.

> …the first and last time I ever did a paint sample was this one and that was in two thousand and-whatever-it-was. And I haven't done one before that and I haven't done one since, so my exposure to it is rare. So you almost learn it real quick while you've got to know it and you eject it out of your mind once you move onto other things (Police Investigator 7)

This suggests that familiarity with one forensic scientific discipline did not necessarily generalise to others.

In addition to facilitating learning, communication via telephone or email was helpful to overcome some practical workplace issues. For example, because investigators had to be logged into the system to check for updates to forensic scientific information, investigators welcomed a phone call or email to alert them of results that were about to be uploaded, especially when results were urgent. Email was valuable because it meant that two-way communication was possible regardless of police investigators' shift times. Furthermore, chains of emails could be saved to case files as accurate records (or an "audit trail") of the communication that took place.

Forensic scientists appreciated the opportunity to interact with police investigators because through responding to the specific questions asked by investigators, they gained a greater understanding of their information needs and experience at pitching their explanations at an appropriate level for a non-scientist.

> …and again that comes from practice where you say something that you think absolutely makes sense and it's so simple to understand and then someone will turn around to you and go, 'Oh, does that mean that?', and you go, 'No…', and when you hear that a couple of times you realise that explaining it that way might not be the best way – that you know, explaining it another way might be a better way of doing it. (Case-Reporting Biologist 16)

Following discussions, forensic scientists reported that they were more confident that the police investigator understood the significance of the findings for the case at hand and that after such personalised educational interactions over multiple cases, perceived that police developed their understanding of the reports in their disciplines.

> I think as time goes on and investigators gain more experience and exposure to DNA evidence um they gain a better understanding (Case-Reporting Biologist 8)

To facilitate communication at the appropriate level, greater awareness amongst forensic scientists of the investigator's investigative considerations was also suggested.

> There is not a real great understanding of the…of the both sides of the story…. they see only their part of giving the evidence in that chain of a whole trial… but they don't get to see the rest of what goes on. (Police Liaison Officer 8)

The frequency of investigators' reported requests for further clarification differed in the ways outlined above. Based on participants' comments, it is not possible to indicate the proportion of cases in which the forensic science required additional discussion. However, what is clear is that the opportunity for discussion, when needed, was seen by participants as vital to the effective use of forensic science in investigations.

3. Organisational Policies and Communication Partners

Participants reported recent improvements in the communication about forensic science due to the organisational policies addressing it. Table 2 outlines some of the organisational policies reported by participants. For the most part, these organisational initiatives were widely supported by participants, as they were seen to facilitate the effective use of forensic science in investigations.

Police investigators were generally satisfied with the communication when they were able to have direct contact with forensic scientific experts.

> it puts us in the position once you communicate, effectively to decide what steps we're going to take next as investigators – it's a very critical component and you know, we've never had any trouble or concerns about the experts that we use because if we can talk to them then that's a great thing (Police Investigator 13)

However, direct contact with forensic scientists tended to be less commonly reported when forensic laboratories were organisationally distinct from policing. Instead, depending on the jurisdiction, police investigators were supposed to contact a liaison officer who was responsible for forensic scientific enquiries by region, by scientific discipline (for DNA), or by case (for major crime).

Table 2.

Organisational Policies Reported by Participants as Having a Positive Impact on the Communication about and Use of Forensic Science in Police Investigations

Type of organisational policy	Examples
Increased resources to support for the use of forensic science in investigations	• increased assessment of, or attendance at, crime scenes by CSEs for high-volume crime • the use of analysts to link multiple unsolved crimes through forensic data • a role for liaison officers to assist police investigators in the management of forensic scientific results for major crime
Increased organisational accord through shared decision making and mutual agreement at the managerial level	• decision rules for the prioritisation of case types and the acceptance of items for examination • agreement on the criteria for reporting findings for intelligence purposes only to assist an investigation when the findings do not meet thresholds for reporting for court purposes

Increased laboratory efficiency and timeliness of result delivery, by relieving forensic scientists of other tasks to allow more time for the examination of high-value items	• limits to the number, and increased selectivity, of items to be submitted for high-volume crime
	• implementation of triaging and vetting processes to prioritise potentially valuable testing and decrease unnecessary testing
	• shifting the role of evidence recovery from DNA specialists to others trained in biological evidence recovery (within forensic biology or police laboratories)
	• requiring that reports for court be requested only if the matter is set for court
	• roles for liaison officers to handle:
	  o receipt and triage of items at laboratories (in discussion with police investigators)
	  o administrative enquiries
	  o enquiries about scientific results in the first instance

Note. The specific blend of policies that were implemented differed according to jurisdiction.

Liaison officers were frequently described as “the face of forensics”, as for many investigators, liaison officers were the only scientific staff with whom any contact was routine. In particular, crime scene examiners, who were one type of liaison officer, were referred to as “our go-to people”. Police investigators reportedly found liaison officers were able to provide support very effectively, due to their understanding of both policing and forensic scientific concerns.

> It makes the whole process a lot easier to understand and communicate with them because they have that liaison now, so it’s been brilliant (Police Investigator 14)

Liaison officers reported that they were usually comfortable about addressing queries that they received from police investigators, but had no hesitation in referring police investigators directly to the scientist if the query was more complex.

> And other times we just say, ‘Look, we’ll put you through to the laboratory – it’s too tricky to give you an answer and we don’t want to be wrong in saying something.’ We don’t want to commit ourselves to saying something and it’s not exactly what the case might be. (Police Liaison Officer 9)

Despite these organisational protocols, police investigators reported that there were times when they opted to contact forensic scientists directly.

> There’s nothing to stop us going direct to the scientists, [the liaison officers] don’t like us doing that but there’s nothing to actually stop us …. and I’ve had many conversations with them myself, to try and clarify from the horse’s mouth exactly what they mean when they give us a result (Police Investigator 21).

Police investigators, liaison officers and scientists all reported that a relationship was important to police investigators.

> I’ve rung them up ‘OK, you mean this, do you? Oh – you mean this. OK great, wonderful.’ And also I’m developing a relationship with them so if I need anything else I can then call on them and it’s all easy rather than a – it’s just, you manage it a lot better (Police Investigator 9)

Indeed, participants in all groups reported that instead of contacting a designated generic email address, police investigators often contacted a specific person who had helped them in the past. This suggests that for most enquiries, it was the availability of a knowledgeable and familiar person for discussion that was most helpful for police investigators, rather than whether that person was a scientist or a liaison officer.

Some forensic scientists acknowledged that the use of liaison officers for enquiries of a general nature enabled them to focus on more specialised aspects of their roles. However, forensic scientists wanted their results to be understood and many perceived an educative function as part of their role. Overall, for their part, forensic scientists concurred that they welcomed enquiries from investigators.

4. Impediments to Effective Communication

Barriers to effective communication were seen to stem from issues with organisational policies, written communication, and opportunities for feedback.

Organisational barriers. Despite agreement amongst practitioners about the need to decrease evidence backlogs and turnaround time for reporting results, concern existed about the lack of shared decision making by policing and forensic scientific organisations, and the potential loss of information that could result from certain policies. For example, some police investigators reported reluctance in seeking clarification about results.

> …when I was in general duties, there would be absolutely no way I'd ring up and say, 'What do you mean by this?', because I just don't know the person, don't want to bother them. (Police Investigator 24)

> I suppose in my whole service we've sort of been warned not ever to annoy the scientists because they're so busy (Police Investigator 16)

This hesitation about contacting forensic scientists represented a disjuncture in the protocol decided within policing, and forensic scientists' concerns that their expert reports be understood.

> I know from people who are in the police, they're told not to waste our time by calling us – no matter what we say on the letter – which is crazy from our point of view…. because you know, if they understand what we're talking about, or we can say it better then we're happy to do that (Case-Reporting Biologist 6)

Similarly, concerns existed amongst police investigators and forensic scientists about the potential for information loss brought about by other organisational policies. Some policies diverted the decision about what to test to a police triage unit, meaning that some of the items of potential interest from the investigator's perspective were rejected for non-scientific reasons. Such triaging of items has the potential to save money (Bedford, 2011), but participants did not always associate financially driven triage with positive case outcomes. The submission of item requests by crime scene examiners rather than by police investigators was also seen to lead to potential information loss in terms of taking relevant samples from an item:

> They take it straight to forensics and it gets lodged straight to forensics but you know….that little request that I write up has that little bit of witness insight, witness and victim insight that they probably don't otherwise know [to inform sampling]. (Police Investigator 20)

DNA evidence recovery by people other than DNA specialists was seen to lead to potential difficulties if re-sampling was required. A decrease in information provided to scientists about a case, as has been recommended to avoid contextual bias (e.g., see the case-manager model for DNA as outlined by Thompson, 2011), was seen to have potential implications for the level of detail that could be provided in reporting, and result in the underuse of scientific expertise. While participants were not necessarily against such initiatives, a perception existed in some jurisdictions that laboratory participation in decision making about policing policies regarding forensic science was mostly in name only. To prevent information loss, there existed a desire for greater partnership, discussion, and participation in decision making.

The presence of noise in written channels. A lack of user-friendliness in expert reports and online systems was of concern to police investigators.

Expert reports. Police investigators viewed the expert reports as very professional documents and assumed that they had to be written as they were due to court requirements. Some police investigators viewed the specialist language used in some reports as a necessity because scientists had to "write them in their own language" and a few investigators even viewed this language as something that added weight and credibility to the report.

During the interviews, police investigators were not asked to paraphrase the terms used to evaluate the strength of evidence; however, many did so to explain a point of difficulty. Although few reiterations of likelihood ratios and other probabilistic expressions retained the scientific uncertainty expressed in the original, police investigators could see that scientists "could not be definitive" and understood that "that's just how they have to say it". Some investigators found verbal expressions helpful, as terms such as "strong support" or "extremely strong support" put the strength of the result into a comprehensible context.

Police investigators acknowledged the difficulty that forensic scientists faced in explaining science. But despite encountering the reports relatively frequently, a large proportion of the police investigators expressed concerns that the language used was difficult to comprehend. The idea of the need to "dumb it down" or use "less scientific speak" was mentioned by many police investigators. In particular, many of the police investigators expressed concern that although they had the opportunity to seek further clarification about the meaning of the reports, jurors and others involved in the criminal justice process did not.

> But also I think that the alleged offenders have a right to understand what the evidence is against them as well. And let's be brutally honest – a lot of them are not as educationally advanced as to be able to understand this kind of stuff – which could be a sort of fairness issue (Police Investigator 4)

Police investigators did not see it as their role to suggest improvements to forensic scientists' reports, lest it be construed as "coaching a witness" or "interfering in the independence of the system". However, certain report features were preferable.

> … they report the findings in a scientific way and I understand all that but I wish…. their summary would be absolutely to the point and to a layman. (Police Investigator 23)

Other comments included that reports were preferred when they: responded to investigative questions; had item descriptions rather than numbers only in the results sections; included an explanation of how samples were numbered and from where they were taken; contained photographs where relevant; and elaborated on the meaning of the results that were presented in tables. Overall, the preferred report features were closely aligned with recommendation for enhancing the accessibility of the reports (Howes, 2015a; Found & Edmond, 2012).

Most forensic scientists reported using uniform report formats and approved wording of evaluative expression, limiting the impact on report clarity that they could make as individual report writers. A disjuncture was evident in the goals of comprehensibility and scientific accuracy.

> I would very much like to make sure that people do understand what I am writing in my reports… I feel like I walk that tightrope sometimes. (Case Reporting Biologist 7)

> They're written from the point of view, not necessarily… of clarity, but from the point of view that …there's nothing you can point at in that report and say it's scientifically incorrect (Case-reporting Biologist 6)

While some recent and ongoing developments at the national level regarding reporting were noted, many forensic scientists remained unsure as to whether these would make reports more helpful for readers, as their focus was also likely to be on scientific correctness and increased standardisation across jurisdictions.

To counteract the difficulties of reports, forensic scientists advocated more education for police investigators.

> … so if I get a query from someone, I will – I won't give them, 'no, yes', and shut them off. I will attempt to give them as much information as they want to take and then if they ask more questions then I will answer more questions…. I think it's important that we do educate them as much as we can so that they understand the value of what they've got or the lack of value, whatever it happens to be. (Case Reporting Biologist 12)

Forensic scientists mentioned various initiatives with which they were involved, including taking an advisory role for an investigative command when requested, giving seminars for investigator training courses, and preparing information for the police intranet or for brochures that were to be distributed to police commands around the jurisdiction.

Online systems. The computer systems of policing and forensic scientific laboratories were linked to greater or lesser extents, as found by Brown et al. (2014). Linked systems were welcomed by participants, but a lack of functionality caused frustrations to police investigators.

> Like one of those entries [on the online system] might be ‘forensic biology assigned’ which you know means very little – because it’s gone maybe to their office but it’s still twentieth in the line and it’s still 3 months away (Police Investigator 8)

Other inadequacies included difficulties in navigation and a lack of clarity in the display of results, with which liaison officers helped to compensate.

> ... there are people that, they don’t use it all the time so when they do hop on and try and have a look at something, they get confused so they just ring. (Police Liaison Officer 9)

> We try to put it [forensic scientific results for the whole case] all together in a, you know, useable format and also to see what you’ve got, what you still need, what you need to go back and get, what you need to revisit – but it’s quite time consuming. (Police Liaison Officer 2)

Lack of feedback inherent in the system. A number of participants from all groups commented that they had not previously had the opportunity to provide or receive feedback on the effectiveness of communication about forensic science.

> Because it’s funny, like you’re involved in this all the time, but no one sort of stops and I suppose it might be more in line with [this research] to have a look at it …. some sort of needs analysis (Police Investigator 12)

Participants reported that there existed some feedback opportunities about the effectiveness of the communication at the management level.

> We put it forward to police pretty much every single opportunity we get that being able to have some type of context is critical for our jobs as forensic scientists. They agree that 'Yes, that is like highly important for it to happen'. It doesn't seem to filter down past the operations meetings. (Case-Reporting Biologist 13)

The work environment reflected a justice silo for many of the forensic scientists interviewed, because there existed limited contact with police investigators (and others in the criminal justice system), few requests to provide further information or explanation, and no feedback on whether or not their results were understood in practice.

> It would be valuable for us to know um whether our reports are being understood well. Because …. I think we're kind of constantly working through trying to improve the structure of our case notes and our case reports. (Case-reporting Chemist 6)

General Discussion

This study explored the communication about forensic science between police investigators, liaison officers, and forensic scientists in Australian jurisdictions. Trends were identified in the communication processes about forensic science from crime scene to court. While on the whole, practitioners perceived that the communication about forensic science met their needs, some areas for improvement were highlighted. In the section that follows, the findings are discussed in light of one- and two-way approaches to communication and some suggestions to address the impediments to effective communication are proposed.

Communication Strategies, Impediments, and Proposed Solutions

One-way communication. In routine cases, when communication is mostly via an online system, the model of one-way communication depicted in Figure 1 aptly describes the communication, which can be seen as a deficit or knowledge-transfer approach. Impediments to effective communication that were evident under this communication strategy, and contributed to the use of two-way communication strategies, related to the lack of user-friendliness in the online system and the difficulties of written reports.

The need for shared computer interfaces or laboratory information management systems to improve the efficiency of communication has been recognised (Strom & Hickman, 2015), and the findings of this study indicated that their implementation has assisted in streamlining the communication from crime scene to court. However, as noted by Brown et al. (2014), not all of the systems adopted by different jurisdictions were equally capable of tracking data through the criminal justice process. Technological glitches in navigating some systems, such as difficulty obtaining an overview of all forensic scientific results for a major case, and showing the progress of items through the laboratory process rendered them less effective currently than would be desirable. When such issues can be rectified in future iterations of the software used, the online component of communication will be further enhanced and may assist in reducing the volume of enquiries about administrative issues.

It may be possible to enhance police investigators' understanding of written reports, if they can be both introduced in police training courses, and made more reader-friendly. It was notable that police investigators' suggestions to help address the issue of report user-friendliness were in line with past recommendations (Found & Edmond, 2012; Howes, 2015a). In addition, because police investigators understood that scientists could not provide definitive conclusions, but not necessarily why not, it may be helpful to include reasons for the form of expression of evaluative opinion within explanatory notes in the reports.

Two-way communication. Supplementary two-way communication was important for negotiating shared meaning between police investigators and forensic scientists in cases involving complexity or unfamiliar scientific disciplines, in accordance with constructivist views of the communication process (Campos, 2007). Discussion was of high importance to police investigators for on-the-job learning about forensic science, and to forensic scientists for learning about investigators' information needs. An educational approach can be part of an overall approach of deference to the authority of scientists' expert opinion, but provides greater understanding and transparency of science (Mnookin, 2001; Roberts, 2002). When a dialogue or participatory approach to communication is used, two-way arrows are appropriate to indicate that communication partners negotiate shared meanings (as seen in Figure 2). One impediment to effective communication under this communication strategy was a perception by some police investigators that it was not permissible to contact forensic scientists, coupled with an apparent lack of awareness about the availability of liaison officers, potentially leading to missed opportunities for relational on-the-job learning about forensic science.

For discussion to be an effective means by which police investigators learn about the forensic science pertinent to a specific case and in general, police investigators need to be proactive in initiating contact with a knowledgeable other. To ensure that police investigators engage in this relational on-the-job learning, whether with liaison officers or forensic scientists, the desirability of such learning should be made explicit and incorporated into police education courses, to accurately reflect the expectations of practice (Birzer, 2003; Oliva & Compton, 2010). Because police investigators preferred to contact a known individual for assistance, reflecting results of past research (Kelty et al., 2013), it would be beneficial, where possible, for practitioners in such contact roles to attend training courses so that police investigators can meet them to establish the relationship for future support with their enquiries.

In recruit and detective training courses, traditional instruction followed by on-the-job learning may be typical and effective for procedural matters (Birzer, 2003; Oliva & Compton, 2010), such as avoiding contamination and requesting attendance by crime scene examiners. However, it may not be as effective for learning higher-level thinking skills (Birzer, 2003), such as applying forensic science to an investigation. Whether or not police education is part of a university degree, providing experience in critical thinking skills, communication, and self-directed learning in the formal education setting, replicating problem-solving in policing practice may be extremely beneficial to investigators (Birzer, 2003; Oliva & Compton, 2010; Werth, 2011). It would be helpful during training to promote self-directed learning about ongoing technological and scientific developments as well as procedural improvements more generally through reliable sources of information about forensic science. Such information sources might include those located on the police organisation's intranet, or information sheets prepared by laboratory scientists, depending upon the preferences by jurisdiction.

Learning stimulated by social interaction and focused on real-world job demands, has been found to be important to participants in policing courses (Oliva & Compton, 2010). As part of a problem- or scenario-based approach (Werth, 2011), participants in investigator training could work through a series of case studies, developed in conjunction with forensic scientists, with access to a forensic science consultant and relevant case reports. Specifically, they would gain experience in using higher-order thinking skills (Werth, 2011) in discussion with others, to apply forensic science to specific cases, integrating their knowledge of the law with investigative skill and forensic scientific results. Practice guided by mentors (Oliva & Compton, 2010), in working through the thinking process for a number of different cases would equip police investigators with a foundation on which to build knowledge through on-the-job learning as needed in practice.

With regards to relational on-the-job learning, in particular, the participants in this study were unanimous in their assessment of the value of case conferences, reflecting past research (Kelty et al., 2013). Participation in such conferences allowed practitioners to engage in shared decision-making about forensic science and overcome some differences that existed between forensic scientists and police investigators in their occupational knowledge and culture, and approaches to language use. Some of the learning achieved in a case conference was replicated in less serious cases through opportunities to discuss item submission with liaison officers. For jurisdictions in which this type of interaction is not currently available, it would be worth considering how such opportunities can be incorporated into practice to further facilitate learning about forensic science.

The organisational policy to use liaison officers to communicate with police investigators about forensic science offers an innovative solution, given that liaison officers are uniquely positioned to understand the needs of both police investigators in the policing context, and laboratory scientists. This communication strategy simultaneously provides more discussion about forensic science for police investigators and frees forensic scientists for laboratory work. A model of the communication of forensic science to account for the use of liaison officers in this communication can be seen in Figure 3. This communication strategy assumes, however, that information can be transferred from the scientist to the liaison officer and from the liaison officer to the police investigator without misunderstanding or the introduction of human error. The main impediment to effective communication evident under this communication strategy was the perceived potential for information loss.

The continuing success of liaison officers' roles in communication about forensic science seems to depend upon high-level awareness of expertise boundaries (Julian et al., 2012) and decision rules about the types of enquiries to forward to forensic scientists. Participants in this study valued interaction with liaison officers and made no suggestion of breaches to role boundaries. However, to overcome the potential negative impacts of introducing another link in the communicative chain, it is essential that open lines of communication exist between liaison officers and scientists to clarify their own questions.

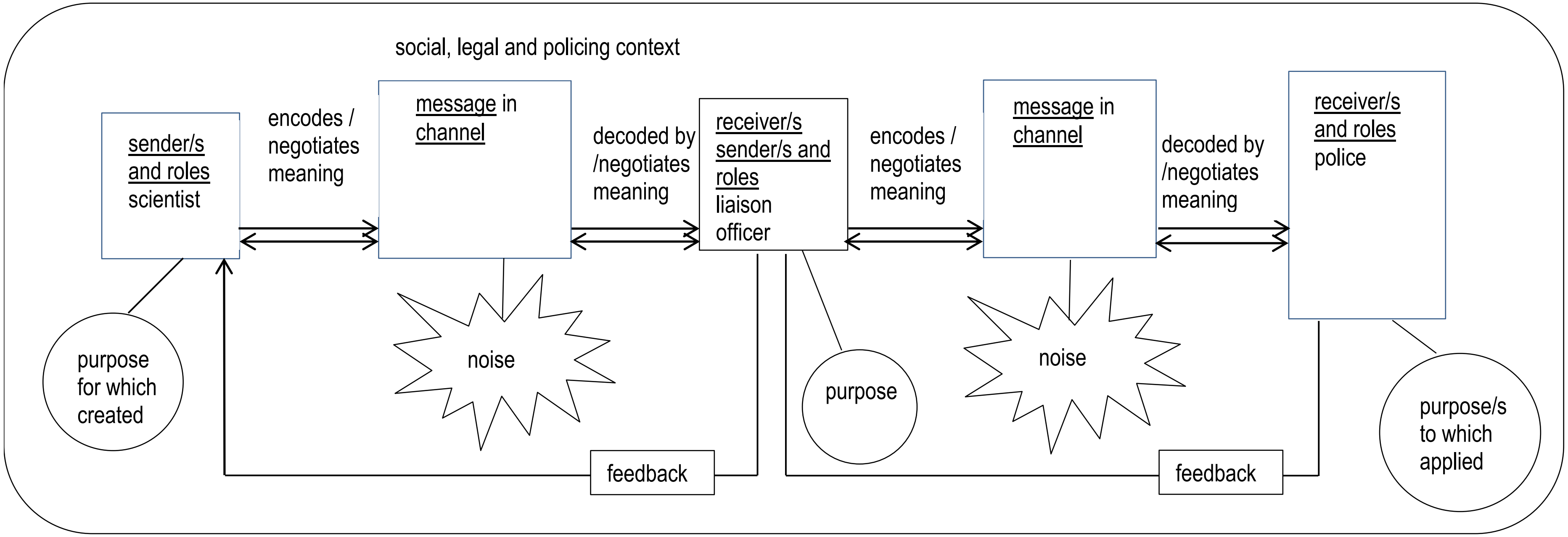

Figure 3. Conceptual model of the communication of forensic science via a liaison officer.

As a consequence of using a liaison officer as an intermediary between forensic scientists and police investigators to explain scientific results, forensic scientists may have decreased opportunities to explain their specialist reports in lay terms. Thus, there is a need for forensic scientists to develop the skill of an explanation in lay terms in other ways, such as through in-house training initiatives (Howes, Martire, & Kelty, 2014). The forensic scientists who participated in this study were keen to think creatively about how to incorporate ongoing professional development opportunities to strengthen such skills, and organisations should aim to facilitate such endeavours.

Researchers have raised the issue of the potential for the value of forensic science to be diminished when decision-making is unilateral, for example if case acceptance policies are determined by laboratories in the absence of feedback from policing organisations (Strom & Hickman, 2015). Many participants in this study acknowledged the importance of organisational accord to ensure that forensic science can provide maximum value to policing endeavours, yet this study highlighted some instances in which decisions about forensic science seemed to have been made by policing organisations without laboratory participation. Accord was seen to be achieved using a dialogue approach to communication (Bucchi, 2008), through regular opportunities for discussion and feedback between policing and forensic science organisations at the management levels. However, given the lack of feedback received by forensic scientists about how well their findings were understood, it may be that organisations could enhance intra-organisational communication, from managers to practitioners. It may be that some particular challenges and frustrations are faced by organisations in preventing information loss when laboratories are organisationally distinct from policing. Such challenges may be exacerbated by practical issues such as geographical and online (email and intranet) separation, heightening the need for regular inter-organisational managerial discussion.

Limitations and Future Research

The current study included participants from every Australian jurisdiction (although not all relevant organisations within each jurisdiction), contributing to an overview of some general trends and issues in the communication about forensic science within the policing context. All participants reported the need for two-way communication under certain circumstances including serious cases, and other cases in which the science was complex, unfamiliar to investigators, or relied upon to advance the case. Such cases represented a larger proportion of cases for some investigators than for others, depending upon the context of their work. On the basis of this study, however, it was not possible to indicate the overall proportion of cases that would require two-way communication about forensic science at one of more stages of the investigative process. Further research would be necessary to attempt to quantify this need.

Although the current study consisted of interviews with police detectives from a wide range of case types, and liaison officers from a range of roles within policing organisations, the forensic scientist participants were drawn from only two disciplines. The communication process from crime scene to court described may differ for forensic disciplines, such as fingerprinting, located within policing commands, and those located more disparately in universities, medicine and other allied health professions, and industry.

This study highlighted some aspects to consider in terms of organisational structure and communication; however, it was beyond the scope of the paper to consider the different organisational structures in detail. Future research could examine whether the value of forensic science differs in measurable ways by organisational approach. Associated with this is a need for further research to develop guidelines that outline appropriate two-way communication to maximise the relevance of findings to investigative questions. Such guidelines may help to allay concerns about impinging upon impartiality through the provision of information to forensic scientists about the case context. Because each jurisdiction has unique features (e.g., Esseiva et al., 2007), case studies would be valuable to illuminate the particular constellations of policies and practices that comprise the approaches adopted by different jurisdictions to overcome challenges in the communication about forensic science.

In the interviews for this study, forensic scientists were asked about their experiences of communicating their findings and expert opinions to lawyers and in court. Interviews with lawyers and judges are currently underway. Further themes about communicating expert evidence from forensic scientists' interviews will be explored in conjunction with contributions from lawyers and judges once those interviews are completed.

Conclusion

This study contributes the perceptions of police investigators, liaison officers, and forensic scientists, to the larger discussion on the effectiveness of communication about forensic science within the criminal justice system. The study outlined the nature of communication about forensic science through the process from crime scene to court, and confirmed the dominance of one-way communication in most cases and at most stages. Two-way communication facilitated police investigators' understanding of specific cases involving complexity and forensic science more generally, placing high importance on two-way communication for on-the-job learning. Discussion helped forensic scientists to better determine the information needs of police investigators, indicating the benefit of such opportunities for scientists' professional development. This study highlighted some valuable organisational initiatives, including the roles of liaison officers in supporting police investigators' use of forensic science, and noted the need to compensate for any decreases in direct contact with scientists through managerial discussion and dissemination of feedback. Organisational initiatives designed to enhance the effectiveness of communication about forensic science, and research aiming to measure effectiveness, should consider not only the timeliness of result delivery but also how well information loss is minimised and police investigators' learning needs are addressed.

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10

Towards Coherent Co-Presentation of Expert Evidence in Criminal Trials: Experiences of Communication between Forensic Scientists and Legal Practitioners

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Abstract

Science and law have been described as a marriage of opposites. each with distinct disciplinary norms, and this dissimilarity has been viewed as an impediment to effective communication between members of these professions. The aim of this study was to explore legal practitioners' and forensic scientists' perceptions of the effectiveness of communication about forensic science in the criminal justice system. Case-reporting scientists (n = 27) who specialised in forensic biology or chemistry and experienced legal practitioners (n = 12) including Supreme Court judges, Crown prosecutors, and criminal defence barristers participated in semi-structured interviews about their experiences of this cross-disciplinary communication. Interviews were recorded, transcribed verbatim, and analysed for patterns and themes relating to cross-disciplinary communication. Overall, participants reported that pre-trial discussion was an essential part of preparation for criminal trials, although defence barristers often preferred to discuss contentious findings with an independent expert. Participants saw the responsibility for relevant, clear, and coherent expert evidence to be shared between forensic scientists and legal practitioners, because it was co-presented to the jury. Implications from the study include approaches to professional development to further improve cross-disciplinary communication, both in and out of the courtroom. Overall, the findings suggest that the relationship between forensic scientists and legal practitioners in serious cases is one of mutual respect and growing understanding.

Towards Coherent Co-Presentation of Expert Evidence in Criminal Trials: Experiences of Communication between Forensic Scientists and Legal Practitioners

The relationship between science and law has been described as a "marriage of opposites" (Wonder, 1989, p. 75). Fundamental differences in the cultures of these social institutions include the way that law uses tradition and precedent to direct action, while science uses incremental advances in research to organise knowledge (Golan, 2004). Throughout the relationship between science and law, in the history of expert evidence, over- and under-valuing of such evidence, disagreement among experts, and expert partisanship have been ongoing concerns (Golan, 2004; Mnookin, 2007).

Nevertheless, scientific expertise is a well-established feature of both contemporary life, and the courtroom experience (Shelton, Kim, & Barak, 2006). Under the exception to the opinion rule in Section 79 of the uniform Evidence Acts (in Australia), experts are permitted to give opinions that are based wholly, or substantially, on knowledge from their training, study or experience (Odgers, 2012). Legal practitioners also communicate about expert evidence in court, leading or challenging expert evidence, referring to it in summing up, and providing judicial direction (Garrett & Neufeld, 2009). This public communication of such evidence is influenced by pre-trial communication between legal practitioners and forensic scientists (Wheate, 2008); yet limited research has explored this behind-the-scenes communication.

The purpose of this paper is to report a study of legal practitioners' and forensic scientists' perceptions of the communication between them about expert evidence in serious cases. I first consider forensic science and communication about it as a human endeavour, outlining some of the issues impacting the effectiveness of communication about forensic science. I then report the findings of the study, and their implications for improving cross-disciplinary communication practices. I identify areas of agreement between legal practitioners and forensic scientists and argue that these provide a bridge between science and law, from which mutual understanding and cross-disciplinary communication can be enhanced.

The Shaping of Forensic Science

The law has played an important role in driving the development of certain bodies of medical and scientific research, such as the long-term effects of exposure to radiation and asbestos (Jasanoff, 2008). However, as highlighted in *Strengthening Forensic Science in the United States: A Path Forward* (National Academy of Science [NAS], 2009), the development of forensic techniques within the legal domain has meant that the hallmarks of science, such as replication of studies, validation of techniques, and peer review have been largely neglected. The report claims that even fingerprinting lacks the research evidence to state that fingerprints are unique (NAS, 2009). Additionally, the NAS Report (2009) noted the potential influence of case context on expert opinion (Dror, Charlton, & Péron, 2006; Kassin, Dror, & Kukucka, 2013), and the need for further research on human elements such as cognitive bias.

To ensure that science is applied to law with the utmost integrity, it is incumbent not only on scientists to validate techniques and guard against bias, but also on the courts to consider admissibility (Edmond, 2014). Newer techniques using audio-visual technology, such as facial and body mapping and voice recognition, are yet to be established by bodies of scientific research (Edmond, 2014). Questions arise regarding the status in law of such emerging techniques and whether purported experts can offer more than lay jurors could see or hear using the same products of technology. A recent High Court decision on a New South Wales case upheld an appeal, such that testimony by an anatomy expert on comparison of a photograph and a CCTV image was inadmissible, as it was not based on specialised knowledge of anatomy (*Honeysett v The Queen*, 2014). By delimiting the bounds of expertise and reaffirming what counts as specialised knowledge, the law shapes forensic science.

The Gold Standard of Human Endeavour

Due to its research culture, DNA analysis has been described as “the gold standard” of forensic science (Lieberman, Carrell, Miethe, & Krauss, 2008). Although DNA evidence has not always been so highly regarded (see Jasanoff, 2008), its position now seems to be well established (Lieberman et al., 2008). However, DNA evidence is not immune to the issues that have plagued other forensic disciplines. For example, questions have been raised about the potential for DNA analysts to be unconsciously biased by the presence of contextual information about a case (Dror & Hampikian, 2011). Different laboratory case management models are seen to suggest greater or lesser potential for the introduction of such bias (Thompson, 2011). On the issue of expertise, because statistical packages (e.g., STRmix and True Allele) have been introduced to assist with the interpretation of DNA profiles, questions arise about whether forensic biologists have specialised knowledge relevant to questions about statistics (Chapman, 2015) or whether they need to have such knowledge.

Even the gold standard of forensic science is neither neutral nor value-free (Jasanoff, 2006). Human decision-making is necessary throughout the process of doing science. In forensic science, these decisions include what to collect at the crime scene and what to submit to the laboratory for testing. At the laboratory, decisions include what to test, how to test it, and how to interpret and report the results. As with any scientific technique, DNA analysis is necessarily based on a number of assumptions and has several inherent limitations (Jasanoff, 2006). Notably, DNA is susceptible to contamination, research about secondary transfer is still at a relatively early stage, and DNA testing is unable to provide an indication of the time that a biological trace was deposited on a particular person or object (Gill & Clayton, 2009).

Recent Australian court cases have highlighted these scientific and legal issues with DNA evidence. For example, the much-cited Victorian case of *Jama v The Queen*, in which a young man was wrongfully convicted of rape, demonstrated the issue of contamination and the failure of the criminal justice system in detecting it (Vincent, 2010). It is not only forensic biologists who need to be aware of the limitations of DNA, but all who are involved with the collection, transport, and storage of biological material, and all who use the results of DNA analysis as a decision-making tool. Justice Vincent's (2010) inquiry into the circumstances of *Jama* cautioned against blind faith in science and overreliance on DNA evidence amongst practitioners at all stages of the justice process.

The South Australian case of *Fitzgerald v The Queen* (2014) highlighted the potential for secondary transfer of DNA and the need for corroborating evidence to determine the time of contact. Technological advances have led to the implementation of more sensitive DNA testing packages (e.g., PowerPlex® 21), and smaller traces of DNA can be detected (Gill & Clayton, 2009). In *Fitzgerald*, the accused had been convicted on the basis of DNA evidence linking him to the scene. On appeal, it was argued the DNA expert in the original trial had acknowledged the possibility of secondary transfer, and there had been no other evidence. Alongside the potential for secondary transfer, there were at least two potential opportunities for the DNA to have been deposited at the scene, and no corroborating evidence; it was impossible to clarify the likely time and context of contact. The High Court quashed the conviction with no order for a retrial due to lack of evidence (*Fitzgerald v The Queen.* 2014).

Collectively, the foregoing examples illustrate the potential for the fairness of trials to be compromised by the idealisation of science (Mnookin, 2007). The appeal process is important in reassessing such cases. The communication of such judgements, and the ensuing academic and media analyses raise awareness amongst practitioners in the criminal justice system, and the broader community, of potential pitfalls with expert evidence.

Forensic Science in Expert Reports

As a component of doing science, reporting on scientific results is a process in which decisions about what to report and how to report it are made. The doing and reporting of science can differ substantially (Schickore, 2008), and reporting is necessarily selective. A number of legal guidelines govern the preparation of expert reports, depending on the jurisdiction. For example, for federal cases, Practice Note CM7 *Expert witnesses in proceedings in the Federal Court of Australia* (Allsop, 2013) should be read in conjunction with Part 3.3 Opinion of the *Evidence Act 1995* (Cth). In New South Wales (NSW), the *Expert Witness Code of Conduct* is provided as Schedule 7 of *Uniform Civil Procedure Rules 2005* (NSW). In Victoria, the *County Court of Victoria Practice Note: Expert Evidence in Criminal Trials* (Forensic Evidence Working Group, County Court of Victoria, 2014) should be read in conjunction with s 189 of the *Criminal Procedure Act 2009* (Vic). Overall, Australian state and federal legal guidelines emphasise that an expert's duty is to the court rather than to a party; the expert opinion is to be based upon specialised knowledge; and the expert report must set out the facts on which an opinion is based, clearly distinguishing between facts and opinions.

While very different expert reports may adhere successfully to the guidelines, empirical research on expert reports in Australian (Howes, Martire, & Kelty, 2014) and US (Siegel, King, & Reed, 2013) jurisdictions documented that substantial differences existed in the extent to which reports provided an explanation of processes, case context known by the expert, notes on interpretation, and detail about assumptions and limitations. It seems that not all forensic scientific reports have strictly adhered, nor have courts required them to strictly adhere, to the legal guidelines for expert reports. It has been suggested that lawyers and judges should routinely critique expert reports in several ways, in light of legal requirements (Edmond, 2014).

In addition to existing legal guidelines on reporting, the NAS Report (2009) recommended that a standard format and language of reporting be developed. In Australia, the recently developed standard on forensic reporting (Standards Australia, 2013) is relatively non-prescriptive, and more informative discipline-specific guidelines are currently under development. Scientists' interpretations and conclusions are necessarily tentative to greater and lesser degrees (Berger, Buckleton, Champod, Evett, & Jackson, 2011). The recently published European Network of Forensic Science Institutes (ENFSI) Guideline (2015) focuses most of its attention on the expression of evaluative opinion. It recommends that all forensic scientific disciplines in participating countries should use a scientifically correct approach to reporting a degree of strength of opinion (ENFSI, 2015). It prescribes the use of likelihood ratios, and associated verbal equivalents, for this purpose.

Despite its focus on using scientifically correct evaluative expression, the ENFSI Guideline (2015) shares some features in common with the legal guidelines for expert reports. For example, the principle of transparency states that "conclusions [are] to be derived from a demonstrable process in both the case file and the report", and "the report [is] to be written in such a way that it is suitable for a wide audience of readers (i.e., participants in the justice system)" (ENFSI, 2015, p. 11). Although the ENFSI Guideline provides limited guidance as to how this can be achieved, other guidelines to support experts in writing for a wide readership are available (see e.g., Howes, 2015a; Found & Edmond, 2012). However, for various reasons, including the nuances of forensic science, the specific circumstances of the case, the amount of information provided to the expert, and the difficulty of writing a single report for multiple readers (Harvey, 2006), it would not be possible for experts to include in their reports all points of potential importance to readers.

Forensic Science in Court

Science can be very persuasive to non-scientists (di Fonzo & Stern, 2007). It has been argued that expertise is constructed in court through the exchanges between counsel leading expert evidence and the expert (Lynch, 2004). If a “white coat effect” exists, such that laypeople trust a scientist’s view over their own, it may impact on the fairness of trials. Although studies with mock jurors have not supported the existence of a white coat effect (Goodman-Delahunty & Wakabayashi, 2012; Goodman-Delahunty & Hewson, 2010), it does seem clear that mock and actual jurors expect forensic science to be presented in trials for particular crimes, before they would be willing to convict (Dartnall & Goodman-Delahunty, 2006; Goodman-Delahunty & Hewson, 2010; Wheate, 2010). Jurors’ expectation of scientific evidence can be seen as part of a broad “tech effect” (Shelton, Kim, & Barak, 2006, p. 333), or as a “weak prosecutor’s effect” (Dioso-Villa, 2015, p. 25), in which technology and science are a part of everyday life. In practical terms, this means that in some cases a jury may need to hear expert testimony about why scientific evidence is not always found at a crime scene (Dioso-Villa, 2015).

Judges may also attribute greater weight to expert evidence than can be justified, despite its limitations in general and in particular cases (Mnookin, 2007). As may be expected due to the variety of scientific disciplines, technological advancement, and inherent complexity of science, a proportion of judges reported that they had heard expert evidence that they had not completely understood (Freckelton, Reddy, & Selby, 1999). Shelton (2010, 2011) argued that judges may be biased in admissibility decisions, tending routinely to allow all prosecution expert evidence into criminal trials. Indeed, in NSW, admissibility rules may have been more strictly adhered to by judges in civil, as opposed to criminal, proceedings (Edmond, 2014). Various arguments about how judges should assess the adequacy of forensic science for court (Cunliffe, 2013; Edmond, 2012, 2014; Jasanoff, 2008) indicate that the challenge is complex and not easily resolved.

Lawyers may also experience difficulties in dealing with expert evidence. It has been documented that from forensic scientists' perspectives, lawyers do not necessarily ask the "right" questions about the science for it to be explained clearly to the jury (Wheate, 2008, p. 128). The challenges of addressing expert evidence seem to be compounded for defence lawyers, with inequality of arms in terms of resources and expertise for trials (Findley, 2008), placing the onus on prosecutors to act as "model litigants" (Kirby, 2010, p. 30).

For defence lawyers, access to experts is subject to a range of factors, including time constraints and the capacity of the defendant, or the legal aid budget, to pay for the expert opinion (Chapman, 2015; Cashman & Henning, 2012). Furthermore, Chapman (2015) noted that when an independent expert is required by defence counsel, it may be difficult to locate one in some disciplines, if most of a state's experts work in the governmental laboratory used by the prosecution. Research indicated that forensic scientists perceived that pre-trial meetings between forensic scientists and lawyers would resolve the issue of inadequate (cross-) examination about science (Wheate, 2008). However, such meetings were not always held, and were often very brief when they did occur (Kelty, Julian, & Ross, 2013).

Judges and lawyers need adequate understanding of expert evidence to communicate clearly about it to the jury. In their study of US cases of miscarriages of justice, for which there had been subsequent DNA exonerations, Garrett and Neufeld (2009) found that flawed expert testimony, and flawed summing-up of such evidence by legal practitioners, was evident in a proportion of such cases that had contained forensic science. Insofar as multiple issues were evident in those cases, flawed communication was not necessarily the reason for the miscarriages of justice (Garrett & Neufeld, 2009); however, the findings offer a stark reminder of the potential to confuse the jury about expert evidence.

The Current Study

The various issues outlined above can be seen as context for the cross-disciplinary communication between forensic scientists and legal practitioners. Despite the potential impacts on the fairness of a trial if the communication between legal practitioners and forensic scientists is inadequate, few studies have explored such communication. This aim of the study was to gain a deeper understanding of: (1) how legal practitioners and forensic scientists communicate about forensic science; (2) how effective they find current communication practices in meeting their information needs; and (3) what they would suggest to improve the communication.

Method

Sampling Procedure

To obtain a purposive sample of participants with relevant expertise (Mason, 2002), letters introducing the research and outlining the experience required were sent to organisations and individuals in each state and territory. These included the chief justices of supreme courts, the directors of public prosecutions, law firms and individual barristers specialising in criminal law, and the directors of forensic scientific laboratories (if separate from police organisations) or the research committees of policing organisations (if under the organisational umbrella of policing). Potential participants either volunteered or were nominated by their organisation and consented to participate. Participants were contacted by email or telephone to arrange a suitable time for their interviews.

Participants

A total of 39 study participants included case-reporting forensic scientists (*n* = 27) and legal practitioners (*n* = 12)[1]. Specifically, the case-reporting scientists included 16 forensic biologists (from seven jurisdictions) who specialised in reporting DNA evidence, and 11 trace evidence examiners (from five jurisdictions) who specialised in reporting forensic comparison of glass. Of the 12 legal practitioners, three were Supreme Court judges (from three jurisdictions), three were Crown prosecutors (from two jurisdictions), and six were criminal defence barristers (from three main jurisdictions). Many of the legal practitioners had experience in more than one role (e.g., both prosecution and defence, or a long career in one of those prior to judicial appointment) and some practised in multiple jurisdictions. Only the home jurisdiction and the primary role involving personal experience of cross-disciplinary communication about forensic science are reported in the participant classifications above.

Materials

Semi-structured interview guides were used for interviews with forensic scientists and legal practitioners. All participants were asked to explain a little about their role in the criminal justice system. Forensic scientists were then asked about their experience of communicating their findings and expert opinions, the influences on the ways they explained, and their perceptions of whether their findings were understood. Legal practitioners were asked how forensic scientific findings and expert opinions were usually communicated to them, what types of communication they found helpful and useful, and how they found the reports. All participants were asked whether they would suggest

[1] The transcripts of interviews with forensic scientists were previously analysed alongside transcripts of police investigators and liaison officers to explore perceptions of the effectiveness of communication about forensic science between forensic scientists and police (Howes, 2015b). Forensic scientists' interview transcripts were re-analysed, following interviews with legal practitioners, with particular attention to the scientists' accounts of communication with legal practitioners and in courtroom contexts.

improvements to current communication practices based on their experience and were given the opportunity to comment on any other aspects of the communication that they wished to raise. On average, interviews lasted about 50 minutes (*SD* = 11.8 minutes). Interviews were by telephone (*n* = 36) or face to face (*n* = 3). Interviews were digitally recorded, transcribed verbatim, and participants had the opportunity to verify their transcripts. Further clarification was received via email from one participant, and minor amendments to transcripts from three participants.

Data Analysis

While listening to the recordings, I read and re-read transcripts multiple times to facilitate immersion. First, patterns of typically reported pre-trial interaction between forensic scientists and legal practitioners were identified. During this stage of analysis, it became clear that forensic scientists were unsure as to why they were not often contacted by defence barristers. A second stage of analysis aimed to explore this issue in more depth. Finally, transcripts were analysed thematically according to the procedures outlined by Braun and Clarke (2006). Open coding was used to record participants' ideas and reported experiences about interdisciplinary communication. Similar codes were grouped together, and through an iterative process, returning to transcripts and checking for confirming and disconfirming evidence, themes were refined. Quotes that best reflected the views of participants were selected to illustrate the three inter-related themes.

Results and Discussion

The results of analysis of the structure of pre-trial communication between legal practitioners and forensic scientists are presented first, followed by the themes about communication, both before and during the trials.

1. The Uneven Structure of Pre-Trial Communication

The structure of communication in serious cases is outlined in Table 1. Some legal practitioners viewed it to be good practice for a defence barrister to meet an expert called by the Crown to discuss the content of the expert report:

> …you might do it just to get an understanding for yourself, particularly if it's critical to your case, you know to the defence flying or not, effectively. (Criminal Defence Barrister 1)

> For instance, if you ask an expert in cross examination, 'Look, you say that – but is this reasonably possible?' ….You want to test that out first. You want to know what the answer is, so you ask them, and you can ask them a series of questions…. It's going to come out sooner or later; best to test it first. (Supreme Court Judge 1)

However, criminal defence barristers provided a number of reasons as to why they preferred not to, or did not, communicate with the state experts. Reasons included not perceiving a need for such discussion, not wishing to give away case strategy, planning to cross-examine the expert in court, and a lack of time and availability.

> Why don't I do that often? Usually, because I'm not concerned about their evidence – or if I am concerned I think I can deal with it without talking to them. And if I do talk to them I will only alert them to the problems in their evidence, and why would I give them a heads up? I want to take it apart in the witness box, not allow that witness to be ready to respond, having been alerted to perceived problems in their report. (Criminal Defence Barrister 4)

As outlined in Table 1, defence lawyers would often have the expert report reviewed by an independent expert, who may either be called to testify or may act in a purely advisory role. However, sometimes it wasn't possible to afford an expert, or to locate a suitably qualified expert.

> … well I've currently got a case where we've got an expert from the US on DNA and from interstate…. But for your run of the mill kind of trial in the District Court for example, you may not have the ability to do that, to get expert, to even review someone else's reports, in which case you might need to phone a friend and get general advice. But really in the large part it depends on the resources available to you (Criminal Defence Barrister 6)

Table 1

Legal Practitioners' and Forensic Scientists' Experience of Cross-Disciplinary, Pre-Trial Communication in Serious Criminal Cases

<table>
<tr><th>Subgroup</th><th>Communication about Forensic Science</th></tr>
<tr><td>Judges</td><td>• usually heard expert evidence when the jury did
• pre-trial evidence hearings were rare in criminal (but not civil) cases
• held voir dire during the course of the trial, in the absence of the jury, to discuss contentious evidence as needed</td></tr>
<tr><td>Crown Prosecutors</td><td>• for serious cases, sometimes participated in case conferences with police investigators from the outset of the case
• if police had requested initial laboratory testing, sometimes requested further testing, or further explanation, at a later stage of the case
• met with forensic scientists
    o to discuss and clarify the expert report
    o to prepare for presentation in court</td></tr>
<tr><td>Criminal Defence Barristers</td><td>• received same expert report as did Crown Prosecutors
• sometimes requested case files of the forensic scientist who had prepared the expert report
• often contacted an independent consultant to review the expert report and case file
• sometimes formally requested an expert report from the independent consultant
• met with the independent consultant to discuss contents of his or her report and prepare for presentation in court (if testifying)
• sometimes arranged for brief pre-trial meeting at court with the forensic scientists who had prepared the expert report requested by the Crown</td></tr>
<tr><td>Case-Reporting Biologists (DNA analysts)</td><td>• although not always asked to testify, when asked to do so for serious cases, many forensic biologists reported that they always aimed to meet with the prosecutors, and sometimes requested a meeting if the Crown had not
• for serious cases, sometimes they had brief meetings with defence, usually at the court (one participant estimated that such meetings with defence occurred for 50% of serious cases; most reported fewer instances; and for less serious cases, such meetings were unusual)</td></tr>
<tr><td>Case-Reporting Chemists (trace evidence [glass] examiners)</td><td>• seemed to be required to testify less commonly than were forensic biologists. When asked to testify for serious cases, brief meetings were typically held with the Crown prosecutors
• when trace evidence was pivotal to the case, far more pre-trial communication occurred with Crown prosecutors than in did when trace evidence was used to corroborate other evidence
• even for serious cases, and with pivotal evidence, pre-trial communication with defence was limited</td></tr>
</table>

Note. These types of pre-trial communication were drawn from interview transcripts of participants in the respective professional groups. In addition to these, forensic scientists reported involvement in preparation and delivery of workshops for legal practitioners on forensic science (e.g., when a new technique or method of reporting was introduced).

The limited communication with defence barristers was perplexing to forensic scientists:

> …very rarely do the defence approach you or talk to you or anything and it seems whilst you're being completely impartial and you're working for the Courts, you're seen almost like you're a prosecutor's witness and prosecutor's only, and it's an interesting thing. I mean sometimes it doesn't happen that way, but in my experience that's what I've found. It's a curious thing …. when I've been to Court, I've had very minimal exposure or question time with defence people and I'm not sure why that is; it's curious. (Case-Reporting Biologist 14)

Most forensic scientists reported very limited contact with defence barristers, but that their court experience was good when defence had spoken with them, because it usually meant a clear focus and line of questioning would be followed.

> So, those opportunities, although they're rare, are really, really good because sometimes you can see the penny dropping, you can actually see them, them going 'Ah, okay, now I get it', rather than them getting very annoyed at us because we're not giving them the answer that they want in the witness box. (Case-Reporting Biologist 16)

All forensic scientists reported their willingness to participate in pre-trial discussions with defence, as well as with prosecution.

> I'm very open with defence as much as I can be. I will educate them in exactly the same way and they will also ask lots of questions about you know, things like studies that are done and what sort of proof and, you know, we supply them with journal articles if they need it and that sort of thing so that they've got, again, the information that they need. (Case-Reporting Biologist 12)

2. Cross-Disciplinary Communication about Forensic Science

The three inter-related themes on cross-disciplinary communication presented below applied both to Crown prosecutors with state experts and criminal defence barristers with independent experts.

(a) Preparation as a shared responsibility to the court. As Table 1 suggests, pre-trial communication between legal practitioners and forensic scientists was limited to instances in which the case was going to trial. The importance of pre-trial communication first arose when commissioning an expert report (although for forensic biology and chemical trace evidence this was usually arranged by crime scene examiners and police investigators; Howes, 2015b). If an expert report did not address the relevant questions, the responsibility was seen to be shared between counsel and the forensic scientist:

> It's important that the expert is properly told, and preferably in writing to avoid confusion, what it is that the lawyer wants – because you'll sometimes get back reports that missed the point, or only spend a short amount of time on the point, but spend a lot more time on some other area that's not really what you were after or isn't in dispute. And often that's not the expert's fault – the expert just hasn't clearly been told what it is that they're seeking. But that doesn't stop an expert getting back to the person requesting it and saying, 'Look, can you clarify just what you're after before I put pen to paper and structure this report?' (Supreme Court Judge 3)

This issue of "settling expert reports" without influencing a witness was raised by a number of legal practitioners, reflecting concerns of police investigators (Howes, 2015b). Such ethical concerns seemed to be problematic for counsel, yet on the whole, legal practitioners in this study concurred that it was important that the expert report comply with relevant legal guidelines and address questions at issue. This finding is congruent with recent literature, which suggests that the main ethical concern should be the obligation for legal practitioners to give adequate guidance to forensic scientists so that their reports are appropriate for court (Blake & Gray, 2012-13; Millett, 2013).

Once a commissioned report had been prepared, legal practitioners regarded it to be essential to discuss its content with the expert. Thus, prosecutors and defence barristers followed a similar protocol for expert reports that they had commissioned.

> And even once the first draft's been obtained, have the expert come in or if the expert's a long way away, you know, confer with them by telephone. I've done telephone conferences with witnesses in England, for example, and America, and you know we just go through their report or their draft of their report. (Criminal Defence Barrister 4)

Forensic scientists agreed that it was important to discuss the content of the report:

> We have a sort of tabulated format in the body of the report where results from the DNA profiles are presented – with no real explanation really – it's very brief. But in an appendix it goes into more detail as to how we've generated the results. So someone [unfamiliar with it] I would think would be quite bamboozled and even after reading the appendix… I don't think would really clarify it very well. (Case-Reporting Biologist 1)

Expert reports which had been requested by police were received as a matter of course by counsel. In these instances too, requests for further information or testing were sometimes made by prosecutors.

Having discussed the content of a report with the expert, legal practitioners reported that they liked to discuss how it would be presented in court. Forensic scientists shared this concern as they required adequate opportunity to explain in court.

> …it's not just the scientist – the barrister's got to know how to get them to explain it properly and bring it down to earth. That's very much the barrister's job. And that's done with preparation – you can't do it on the spot –….The barrister's got to be at one with the witness and they've got to understand each other, because sometimes you get witnesses talking at cross purposes with the barrister and it can get very confusing. You've got to spend time with them. (Supreme Court Judge 1)

> …if we can [talk] with the lawyer and go through those a little bit more in depth that then gives them a little bit more knowledge as to why that is quite a significant point and we should probably make sure that the jury are fully aware as to why ….that factor is important in interpreting these conclusions…. So yeah, I think for us to be able to give them a little bit more information [makes] it easier for them to make our life easier to get the information across. (Case-Reporting Chemist 2)

Presenting the evidence was of particular importance in jury trials. Legal practitioners referred to thinking of analogies and metaphors that would help jurors understand forensic science.

> …really good expert witnesses will do it and they'll usually do it with a good old-fashioned metaphor or analogy…. all jurors understand things and putting things that they don't understand into a context of things that they do understand is a tool…. and then I might get some of my more important witnesses into my office to run through some metaphors and analogies… you know, if blood hits a wall square on, it creates an even circle. If it hits going from left to right it creates an elliptical pattern going left to right….and you can use raindrops going on the windscreen and that type of stuff, is what we kind of search for. (Crown Prosecutor 1)

Forensic scientists discussed in-house training initiatives, reflecting on their own court performance, thinking of different questions that might be asked by prosecution and defence and how they would answer, and practicing explanations of complex concepts on their colleagues, friends, and family members.

> …we do court room evaluations, and so every six months we're supposed to get court room evaluation, but that isn't from a jury perspective ….they're actually really quite limited – it's just a tick box. I suppose people won't do them if…. it requires more information than the tick box (Case-Reporting Biologist 15)

In terms of their own preparations, legal practitioners noted that they read intensively about specific aspects of expertise relevant to the case, and thought through and prepared for a range of contingencies.

> I find it hard to go to court if I don't know everything – I get nervous so I think, you know, you've got to get across it….and I don't always – I'm speaking from an imperfect stance – but you've just got to make time and you've got to find someone to tell you – because you *won't* learn it by reading Google. (Criminal Defence Barrister 5)

> …and I know it sounds bad but sometimes you learn by mistakes, being in the job, it's like, 'I probably should have asked for that in advance', and I don't like surprises come trial. I like to know what's there and how good this fingerprint really is…. or how good is the comparison as far as the DNA goes with the amount of DNA material and the profile that you get, how strong is it? (Crown Prosecutor 3)

Depending upon the way the trial unfolded, taking into account various logistical and practical issues, this preparation could be drawn upon as needed.

(b) Disciplinary and cross-disciplinary discourse norms. While legal practitioners and forensic scientists shared the concern that expert evidence be understood by jurors, some differences in approach to communication were evident.

Cross-disciplinary differences. Both legal and scientific discourses are specialised and use language in ways that are shaped by disciplinary norms (Eades, 2010; Hagge, 1997). Legal practitioners and forensic scientists typically described communication in ways that corresponded with disciplinary norms. For example, lawyers used words such as "persuasion" and "argument"; while scientists referred to "peer and technical review" and "scientific correctness".

Persuasion. Legal practitioners were concerned that people from outside the law misunderstood their notion of persuasion, which referred to presenting a sound argument.

> …and it's up to the parties with their strengths of chief- and cross-examination and their persuasive skills and address, to demonstrate that their arguments are to be preferred to their opponent's. (Criminal Defence Barrister 3)

Participants explained "persuasion" was not used in the sense of "manipulation". Instead, persuasion was an exercise in presenting information, in a way that the judge and jury could follow.

> I think, I think what's missed is in the art of persuasion, the art of advocacy, that it's not limited to arguments and submissions about a case but it includes the way your facts are presented. For instance the manner in which the evidence-in-chief of the witness is presented during a trial can be persuasive even though it's an exercise in advancing fact. (Supreme Court Judge 3)

As such, legal practitioners saw persuasiveness as a quality of good communication that also applied to expert evidence.

Correctness. In forensic scientists' accounts, accuracy referred to ensuring that results were expressed conservatively and decisions made in the course of the examinations could be justified (e.g., sampling decisions and rationales for using particular analytical techniques or selecting particular population databases). Scientific correctness was an overarching concern in reporting; however, forensic scientists wanted their reports to be understood:

> The wording of our results might be better understood if we used different wording, but then I don't know what sort of wording you could use without, you know…you want to be conservative in your approach. From my perspective, I want to be conservative – but everyone else wants to understand exactly what you're saying. (Case-Reporting Biologist 8)

This approach reflects the ENFSI Guideline (2015) with a focus on scientific correctness, and an acknowledgement of the need for expert opinion to be given in a way that can be understood by the range of stakeholders. Concern for both scientific and legal correctness of expert testimony is important, because incorrect wording could be grounds for an appeal. Past research has indicated that judges share this concern with forensic scientists. For example, although judges wanted to be understood by jurors, they reported that their overarching concern was for correctness of judicial directions in order to avoid an appeal (Ogloff, Clough, Goodman-Delahunty, & Young, 2006). Thus, some judges reported reading directions to the jury from a bench book, despite complexity or superfluousness to a case (Ogloff et al., 2006).

Coherence as a cross-disciplinary similarity. In-depth discussion about communication revealed more similarities than it did differences between the professional groups. Not only were participants united in their concern about jurors' understanding, but that this necessitated that communication be "clear", and that information be presented in a "logical" or "coherent" sequence. In court, coherence referred to "establishing a foundation" or "providing the basics and building from there". The overall cases presented needed to be coherent:

> …and then there's probably the most crucial decision to be made in running a jury trial and that is….what narrative best enables the jury to receive the evidence? So the narrative, you know…. is there evidence that they're receiving that needs some base before they can receive that evidence? You know, starting from the ground up, what is the best narrative in which to give the evidence? (Crown Prosecutor 1)

This view makes sense from the story model of juror decision-making (Pennington & Hastie, 1986). From defence point of view, it accords with the practice of presenting alternative yet plausible narrative accounts as to how the evidence may be explained.

Participants concurred that the forensic scientific evidence needed to be presented as a coherent whole in its own right.

> Starting from basics, and explaining each step in a logical sequence, in simple English and giving an explanation as to why and how, not just what, I guess are all very important. (Supreme Court Judge 2)

> With a jury, of course, you can't assume anything. So you really do have to start and make sure that they understand the basics through, and also then that depends on your prosecutor as well. (Case-Reporting Biologist 12)

Although the jury held a position in the forefront of practitioners' collective minds, it was nevertheless relatively abstract, due to the lack of interaction with and feedback from the jury.

> I like to try and make eye contact with them, particularly when I'm explaining scientific concepts. You know, sometimes it helps …to look at their faces and, and try and gauge whether they're understanding what you're saying, you know. Do you perhaps need to rephrase something or, give a clearer explanation or, you know, talk about something for a little bit longer just to make sure it's understood….[But] ultimately I will never know whether they've understood my evidence or not. (Case-Reporting Chemist 5)

By contrast, judges were not viewed as an unknown entity to the same extent because they were familiar with expert evidence and could seek clarification as required during a trial.

> …but sometimes when it's, you feel like you're wading through treacle and you know that there's just a question that needs to be asked which will clear it up, then ….I do. (Supreme Court Judge 2)

> So I think the Judge's role is to really nurse along the less competent examiners and cross examiners to make sure that it's actually understood what it is the witness is saying because sometimes the questioner fails to clarify that. (Supreme Court Judge 3)

Forensic scientists reportedly found it helpful when judges asked questions, as it provided them with feedback on whether or not the explanation had been clear, and what aspect had been unclear; this was helpful in guiding forensic scientists' thinking about how best to express similar ideas in future cases.

Cross examination about forensic science was also seen to help to give a balanced view of the evidence, if the prosecutor's examination-in-chief had not adequately done so:

> And you know there have been occasions here where [forensic scientists from our team] have given evidence and where they've wanted the defence to ask them the question because they feel that the evidence that's being led by the prosecution for them, is being made to look too strong (Case-Reporting Biologist 6)

Thus, the perception of a shared responsibility to communicate expert evidence clearly for jurors was evident in participants' responses. Essentially, participants viewed the presentation of expert evidence from the jury's perspective, as co-presentation of expert evidence. Because of judges' experience with expert evidence, and because they could ask for elaboration or clarification as required, a less detailed approach tended to be taken in judge-only trials.

> Judge alone… I would lead enough so that I am satisfied that it's appeal-proof so that you've got a basis of, for the ultimate opinion being drawn and expressed – but I'd probably do it in a quicker fashion, because a judge has heard DNA evidence regularly in court and you don't really have to educate them on the science itself. It's just making sure that there's enough that can't be challenged on appeal. (Crown Prosecutor 3)

Deference to cross-disciplinary colleagues' judgement. Although responsibility for clarity was a shared concern, some elements were deemed to be the province of the cross-disciplinary colleague. For example, the specific wording of evaluative expressions seemed to be clearly the domain of the scientist.

> I think that's always the, that's the sticking point, that they want us to say something about the likelihood ratio but we can't actually say something that it doesn't actually represent. (Case-Reporting Biologist 4)

> Well, part of our training is, we're trained to not to use language – such as reporting that things are 'the same' or that things are 'a match' and the same goes for like a Court situation. We're trained to avoid being drawn into that sort of language and terminology because really, scientifically, it's not correct. (Case-Reporting Chemist 5)

Some forensic scientists reported that they had developed, were in the process of developing, or would like to develop visual aids for their presentations in court.

> What I do offer the prosecutors is and they very rarely take it up is an – I'm willing to give PowerPoint presentations in court – perhaps go through the basics (Case-Reporting Biologist 1)

The effectiveness of such presentations in assisting jurors with grasping the basics of DNA evidence, for example, has been supported by research (Goodman-Delahunty & Hewson, 2010). However, because forensic scientists did not know the details of specific cases or whether their evidence played a large or small role in them, decisions about whether to use visual aids were the domain of counsel leading the evidence.

These examples indicate respect for cross-disciplinary colleagues' expertise and awareness of the limits of role boundaries, which is one important factor in ensuring the integrity of forensic science in the multidisciplinary context of the criminal justice system (e.g., at crime scenes; Julian, Kelty, & Robertson, 2012).

(c) Evaluations of cross-disciplinary colleagues' communication practice. Participants reported different levels of skill in co-presenting expert evidence amongst their colleagues in different disciplines. Participants elaborated on how they perceived that their interdisciplinary colleagues' approaches helped or hindered them in achieving clear and coherent communication about forensic science.

Legal practitioners reported that from their perspective, in addition to adhering to the relevant practice notes or codes of conduct for expert reports, "good expert reports" provided: a clear summary of the overall report; headings; responses to the questions asked; explanations of technical information in lay terms; and distinguished the opinion from the information on which it was based. Legal practitioners preferred that more information to be included, if it was relevant, particularly in the event that a case was to be heard on appeal.

> …it's too late to get [further information] once you've been through the trial…. the shutters go down (Criminal Defence Barrister 2)

Overall, legal practitioners' observations about expert reports accord with those made by police investigators (Howes, 2015b) and recommendations for readability based on theory and research (Howes, 2015a).

Legal practitioners perceived that some forensic scientists were able to explain clearly in court and were well-practised and skilled at doing so. Such scientists could be asked to explain, with a minimum of intervention from counsel leading the evidence.

> Look, some are really good in the witness box and it's almost the matter of pressing play and they give a great overview of the evidence and explain in lay terms and they're very well-rehearsed and practiced in doing it. (Supreme Court Judge 3)

> I think forensic scientists have got better at court evidence; they've got smarter at it. They're prepared to give those concessions; they're willing to concede those points to acknowledge the limitations of testing. (Criminal Defence Barrister 1)

On the other hand, legal practitioners perceived that poor communication by an expert could be avoided through pre-trial communication, as outlined above, and in the trial stage by carefully constructing questions to focus the expert on issues of relevance to the court.

Forensic scientists reportedly found their role of giving expert testimony to be made difficult when they were not asked questions that elicited effectively their findings and expert opinion, reflecting past research (Wheate, 2008).

> …when you're getting questioned on the stand, if you don't know what they're asking, because they don't know what they're asking, it can get really difficult to answer – whereas, if they've got a bit of knowledge, their questions are usually a lot more relevant. (Case-Reporting Biologist 11)

Some forensic scientists reportedly found it helpful when counsel provided an opportunity for them to suggest questions that might help to present the scientific evidence in court.

Forensic scientists reported that implausible scenarios were sometimes proposed by the defence to account for the presence of scientific evidence, whereas plausible alternatives existed and may have helped the defence case.

> … and then the defence stands up and says, 'Oh no, I don't have any questions', or they ask for something irrelevant and they don't ask the question that, to our minds is sometimes the burning issue. (Case-Reporting Biologist 6)

At times, forensic scientists found it difficult if lawyers had become familiar with scientific terms and used them in examination or cross-examination. Judges concurred that it was difficult to understand when this happened:

> …well, I think what happens is, some lawyers get so caught up with…. they've become temporary experts in an area – they forget that their audience hasn't done all of that advance work and …they forget therefore to bring it back to simple terminology. (Supreme Court Judge 3)

For those who were aware of this pitfall, it was something to guard against:

> I mean, it's part of being a lawyer – being a lawyer you need to develop an understanding of a large number of expertises – you know, from pathology through to forensic accounting….You know a little bit of old-fashioned childhood wonder goes a long way, like just having a curiosity about something – and you know, if you can maintain that curiosity that's a valuable tool. (Crown Prosecutor 1)

For forensic scientists, use of scientific terms by lawyers meant that if the nuance was slightly incorrect, forensic scientists had to correct counsel under the public gaze in court; this was seen as an awkward kind of obligation, which also had the potential to confuse the jury. Also difficult for forensic scientists was counsel's insistence of brief responses to questions that were necessarily nuanced and complex. Instead, the opportunity to explain was highly valued:

> Other lawyers just want you to give a 'yes' or 'no' answer. And again, you know, there have been times – not all the time – but there have been times when I've asked the magistrate or the judge, 'May I be able to expand on that and give my reasoning behind it?', and again it's very dependent on the magistrate or the judge. (Case-Reporting Biologist 16)

Forensic scientists' duty was to the court, and also it seemed, to the accurate representation of science. For all of these reasons above, from forensic scientists' viewpoints, the most helpful thing that legal practitioners could do to enhance the communication of forensic science would be to make time for pre-trial discussions and to provide adequate opportunity for explanation in court. All of the legal practitioners who participated in this study, and specialised in serious criminal cases, agreed that pre-trial discussion was important, and reported holding discussions routinely in practice. However, the collective experience of forensic scientist participants suggested that discussion with prosecutors and defence barristers was not routine for the full range of their cases, differing both by jurisdiction and case type. Past research has highlighted the role of time and budget constraints in this regard (Cashman & Henning, 2012).

General Discussion

This study aimed to shed light on legal practitioners' and forensic scientists' perceptions of the effectiveness of communication about forensic science in the criminal justice system. Practitioners' experiences of the nature and form of behind-the-scenes communication that occurs in the lead-up to court, as well as in-court communication, were explored. The key finding of the study overall, was that for serious cases, participants implicitly understood themselves to be co-presenters of expert evidence to the jury, and this drove pre-trial communication. Participants perceived shared and individual responsibility for high-quality preparation and were in a symbiotic relationship when leading and giving expert evidence.

The notion of co-presentation is compatible with the idea of the jury as an audience and the courtroom as a performance (or presentation) space (Jasanoff, 2008). In this regard, even judges were co-presenters of expert evidence in jury trials, intervening as necessary, for the sake of clarity and coherence, which emerged as a cross-disciplinary discourse norm. The co-presentation of forensic science in court reflects the centrality of the jury in the collective mindset of legal practitioners and forensic scientists. Understanding expert evidence in a trial as co-presentation of forensic science at the case level accords with a broader understanding of the shaping of forensic science by law (through precedent and appeal decisions) and science (through research and validation of techniques). In this part of the paper, implications of the findings are discussed.

Facilitate Discussion Opportunities for Defence

The defence plays an important role in ensuring the procedural fairness of trials (Edmond & Roberts, 2011). This role ideally involves testing the robustness of expert evidence, including its limitations, methodology, and alternative interpretations, rather than limiting cross-examination to questions about the chain of evidence, to ensure that the triers of fact can be given a balanced view (Edmond & Roberts, 2011). To facilitate this endeavour, it is necessary for defence lawyers to have an adequate understanding of the particular forensic scientific discipline in relation to the specific case. The intensive reading reportedly undertaken by barristers in this study was seen to be necessary in conjunction with, rather than in place of, advice from a suitably qualified expert.

Cross-disciplinary, pre-trial discussion about forensic scientific findings and expert opinions reportedly helped legal practitioners and forensic scientists to work effectively in their roles. It meant that it was more likely for expert reports to address issues of relevance to the case, report content to be understood, and expert evidence to be co-presented coherently in court. Defence barristers' reported preference to engage an independent expert highlighted a disjuncture between forensic scientists' and defence barristers' perceptions of the impartiality of state experts. One reason given for this preference was that it was best to cross-examine an expert in front of the tribunal of fact, so that the contents of the report could not be amended. This position is supported by advice given by Edmond et al. (2014) who suggested caution in addressing queries in a *voir dire*, as opposed to in the trial, lest the report be amended to address such queries. Cognitive bias, by definition, operates outside conscious awareness (Thompson, 2011); therefore, it is understandable that doubts exist as to the capacity of any professional to be truly impartial.

However, forensic scientists in this study expressed concerns about lost opportunities to challenge forensic scientific evidence. It may be that defence lawyers currently underutilise the services of forensic scientists from state laboratories, even at brief meetings outside the court. Furthermore, the results of this study reflect Chapman's (2015) concerns, suggesting that defence barristers may not always have adequate access to experts. While independent experts from many disciplines drawn from the health, university, and industrial sectors, may be located with relative ease for the defence this was apparently far less so for DNA experts.

To improve the quality of cross-examination of experts, the use of key questions (Edmond et al., 2014), and pre-trial conferences to focus on the most relevant issues (Wheate, 2008) have been suggested. However, given the issue of access to independent experts with whom criminal defence barristers can discuss contentious aspects of forensic science, providing adequate access to experts for defence barristers may require creative solutions. Within policing organisations, some jurisdictions have a DNA Help Desk or a DNA Results Management Unit, from which liaison officers address queries from police investigators, referring them to specialists as needed (Howes, 2015b). It may be possible for an initiative, such as a confidential DNA enquiry service, to be developed and piloted for defence barristers. Adequate access to experts would enhance the quality of cross-examination, and therefore the fairness of trials and safety of verdicts.

Build on Similarities to Increase Understanding

Cross-disciplinary practitioners in this study shared common ground, including the responsibility to the court for adequate pre-trial preparation and the goal of presenting evidence clearly and coherently to the jury. The shared focus on the jury, and the cross-disciplinary discourse norm of coherence, offer a bridge between disciplines, from which to develop deeper mutual understanding. Psychological research has tested the notion that intra-group communication (e.g., between criminal justice practitioners) is better understood by the interlocutors than is inter-group communication (e.g., between forensic scientists and legal practitioners). Results from experimental studies support this hypothesis, and suggest that by adjusting the conception of the group to a more inclusive one (e.g., professionals associated with the criminal justice system), understanding of previously inter-group communication can be enhanced (Greenaway, Wright, Willingham, Reynolds, & Haslam, 2015).

Workshops that offer professional development on topics of mutual interest provide an opportunity to develop a shared identity and mutual understanding as professionals associated with the criminal justice system. For example, an Expert Evidence Workshop hosted by the Australian and New Zealand Forensic Science Society and held in July 2013 in Hobart (ANZFSS, 2013), was attended by forensic scientists, prosecutors, criminal defence lawyers, academics, and graduate students. Appropriate topics for interdisciplinary workshops may include: insights on presenting expert evidence to juries; cognitive factors in trials; and implications of new practice directions, forensic standards, or codes of conduct.

To facilitate cross-disciplinary understanding, prior to commencing their careers, interaction between prospective forensic scientists and legal practitioners would be valuable. In one such initiative, offered at the University of Lausanne in Switzerland, a case-based approach was taken to the study of expert report writing (Biedermann, Voisard, Scoundrianos, Furrer, Taroni, & Champod, 2014). According to student evaluations of the course, it benefitted students of both forensic science and law, developing interdisciplinary understandings, critical reflection of their own practice, and facilitating greater skill in writing and reading expert reports (Biedermann et al., 2014).

As outlined in the first part of this paper, expert evidence is not infallible; critical thinking about it is necessary, to prevent the issues of the idealisation of science impacting on the fairness of trials (Mnookin, 2007). The findings of this study indicated that potential misunderstanding of the nuances of science is an ongoing concern for forensic scientists and a challenge for legal practitioners. The purpose of allowing expert opinion is to assist the court and legal practitioners cannot be expected to understand the intricate details of the range of expertise that they encounter. However, courses that examine forensic science as the object of social scientific enquiry would help prospective legal practitioners to develop a non-idealised understanding of science and critical thinking about the use of expert evidence in trials (Williams, 2015). Such forensic criminology and forensic studies courses are available at a number of universities For example, at the University of Tasmania, Forensic Investigation, offered within the Criminology and Sociology course structure, may be elected by undergraduate students in Law, Policing, and Psychology, while Forensic Science in Society may be elected by students from any discipline (University of Tasmania, 2015).

For forensic scientists, given the importance of communicating complex concepts clearly to non-scientists in writing and in speech, taking courses in science communication during university education may be beneficial. Such courses encourage students, who are drawn predominantly from science and journalism courses, to step away from disciplinary norms of language use and to develop flexibility in their writing. Students develop their ability to communicate about science with members of the public, who may share an interest in science, although they are not specialists in it (Bushnell, 2003; Longnecker, 2009). Flexibility with writing would assist forensic scientists to meet the various reporting guidelines, while maintaining coherence for non-scientist readers.

Explicitly Value Communication Excellence

This study also noted that different levels of skills were observed by cross-disciplinary colleagues in the communication and co-presentation of expert evidence. Ongoing professional development to enhance communication skills is important. Forensic scientist participants in this study reported participation in in-house training programs. Such programs need to meet certain criteria to be most effective (Cunliffe, 2014). In addition to learning *about* good presentation, in-house training programs should offer participants opportunities to practise it (Howes et al., 2014) and to receive formative feedback from peers to guide development (Cunliffe, 2014). It would be helpful to forensic scientists after giving evidence, both to conduct a self-evaluation and to receive peer feedback. While such opportunities currently exist in some jurisdictions, participants in this study reported that such peer feedback was typically limited. Feedback should ideally provide a discussion of strengths and weaknesses of the performance. Initiatives within existing communities of practice (e.g., Howes et al., 2014) could be strengthened by formalising them and explicitly recognising their value within the in-house training programs.

Researchers have documented that legal practitioners did not find it beneficial to take compulsory professional development courses on forensic science because they were not helpful for the specific issues of forensic science relevant to their case load at the time (Cashman & Henning, 2012). Some of the legal practitioners in this study were involved in advocacy and expert evidence training programs. However, currently, despite the ubiquity of expert evidence, legal practitioners in Australia are not obliged to undertake professional development in expert evidence (see e.g., Law Institute of Victoria, 2015).

Professional bodies could adjust their criteria to allow legal practitioners to receive credit for the (documented) intensive reading and consultation with experts that they currently undertake in the course of trial preparation. Such a self-directed approach to professional development is appropriate for professionals, because would allow practitioners to focus on relevant concerns as needed, which is associated with lifelong learning (Hewitt, 2012). The forensic scientists in this study perceived their role to include an educational component, to meet their cross-disciplinary colleagues' needs for general and case-specific information about forensic science. To allay practitioners' concerns about the ethics of cross-disciplinary interactions, an open discussion between the professional bodies of forensic science and law about the parameters within which necessary discussion and professional development can reasonably occur may be helpful.

Limitations and Future Research

This exploratory study aimed to provide an overview of forensic scientists' and legal practitioners' perceptions of the communication about forensic science in the criminal justice system. Although fewer legal practitioners participated in interviews than did forensic scientists, the disparity in group sizes was not of concern. Participants had high-level expertise in their roles and routine use of expert evidence within them, meeting the aim of purposive sampling (Mason, 2002). All forensic scientists included in the study were government agency experts. Research that specifically explores the experiences of defence experts from independent, governmental, and overseas laboratories may provide valuable insights.

It was not possible to include practitioners from all forensic scientific disciplines or levels of the court system. However, the forensic scientist participants had experience in different levels of courts and legal practitioners had experience with different forensic scientific disciplines, highlighting some concerns and need for future research. Specifically, forensic scientist participants referred to decreased opportunities for discussion with police prosecutors in less serious crimes and lower profile cases. Research that aims to establish the communication needs of legal practitioners for less serious cases is an area that warrants further exploration. Legal practitioner participants often referred to particular difficulties with expert reports and testimony with experts from health professions, including medical, psychiatric, and psychological specialisations. This reflected findings from police investigators' experiences with experts (Howes, 2015b). Further research that includes representatives from these professional bodies and health professions is warranted.

Conclusion

This study contributed forensic scientists' and legal practitioners' perspectives on the effectiveness of communication about forensic science in the criminal justice system. It highlighted the way in which a forthcoming trial drove pre-trial communication between forensic scientists and legal practitioners. According to participants of both groups, good communication about forensic science in a trial occurs when it is co-presented effectively. Such co-presentation necessitates adequate pre-trial discussion about the content and form of the presentation. Shared concern about the jury, responsibility for preparation, and the common disciplinary norm of coherence can be seen as a bridge from which to build greater cross-disciplinary understanding between forensic scientists and legal practitioners. Interdisciplinary education is warranted and cross-disciplinary interaction could be recognised and valued as part of ongoing professional development, both in forensic science and criminal law. Further research about legal practitioners' communication needs in the context of less serious cases and with experts from other disciplines would be valuable. Overall, it seems that for serious criminal cases in Australia, the relationship between practitioners of forensic science and law can be characterised as a respectful working partnership. Within this partnership, regular communication fosters deeper understanding of the complexity and nuance of both science and law.

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Part 5

Project Summary and Conclusions

11

Project Summary and Conclusions – Communicating Expert Opinion: What Do Forensic Scientists Say and What Do Police, Lawyers, and Judges Hear?

Project Summary and Conclusions – Communicating Expert Opinion: What Do Forensic Scientists Say and What Do Police, Lawyers, and Judges Hear?

The report published in 2009 by the National Academy of Science, *Strengthening the Forensic Sciences in the United States: A Path Forward* reflected an international shift in thinking about forensic science. The report highlighted the importance of conducting research not only to advance and validate the techniques of forensic science, but also to examine the ways in which forensic science is socially constructed and used in society. Since the publication of the 2009 NAS Report, research has burgeoned on various aspects of forensic science, including forensic studies research (Williams, 2015) that aims to address the issue of the communication of expert opinion. This PhD research project, “Communication of expert opinion: What do forensic scientists say and what do police, lawyers, and judges hear?” represents part of that increased impetus to conduct research on forensic science as an object of social enquiry.

The purpose of this chapter is to summarise the aims and findings of the research project overall, and to highlight its contributions to the broader field. Overall, the thesis contributes deeper understanding of the nature of written and verbal communication of forensic science between forensic scientists and police, lawyers, and judges. It highlights the need not only to meet legal and scientific guidelines on reporting, but also to communicate in ways that meet cross-disciplinary practitioners’ needs. The thesis provides some general and some more specific recommendations to assist in achieving improved communication, understanding, and use of forensic science in the criminal justice system. While the contributions of the research were highlighted throughout the project at the end of each each chapter, they are briefly summarised and synthesised in this chapter. Limitations of the project are considered and directions for future research are proposed before the chapter concludes.

Contributions of the Research Project

Introduction, Background, and Methodology

As outlined in **Chapter 1**, this research project aimed to explore a contemporary research issue, of interest to the forensic science sector, and sponsored by the Australian Federal Police. Specifically, the issue considered was the effectiveness of communication between forensic scientists and police investigators, lawyers, and judges. The overarching aim was to enhance the effectiveness of the communication of the findings and expert opinions of forensic scientists in the criminal justice system. The scope of the project was necessarily limited to considering the communication practices within Australian jurisdictions, and two scientific disciplines were investigated. Forensic biology and chemistry were selected because their high level of specialisation would potentially make them difficult for non-scientists to understand. As noted in Chapter 1, the communication of findings and expert opinion is an issue that is not unique to any one scientific discipline, field of expertise, or criminal justice system. This meant that the recommendations of the project would potentially have applications for the communication of forensic science internationally.

In **Chapter 2**, I reviewed literature on communication and science communication. Using a communication model as an organisational framework, I then reviewed past research and commentary on the communication of forensic science in the criminal justice system. Two of the under-researched aspects of communication about forensic science, which were identified in the review, became the specific focus of this research project. First, a substantial body of research had considered the communication of expert opinion in the form of expert testimony to jurors in the courtroom, despite the relatively small proportion of cases that go to trial (Blumenthal, 2002). This left a dearth of research about the effectiveness of communication of expert opinion to police, lawyers, and judges, who routinely use the expert opinion in their roles in the criminal justice system. Second, past research focused on the message of the expert opinion. More specifically, it focused on the wording of expert opinion in terms of the weight of evidence, whether expressed in verbal or numerical terms (e.g., Martire, Kemp, Watkins, Sayle, & Newell, 2013; McQuiston-Surrett & Saks, 2008, 2009). The rationale was established to explore expert reports and other formats of professional communication between forensic scientists and police investigators, lawyers, and judges.

In addition to providing the rationale for the project, the chapter contributed an approach to thinking about the communication of forensic science. Communication via a transmission model provided a useful heuristic for considering the communication of forensic science in the criminal justice system and as an organisational framework to use to synthesise past research. However, the chapter highlighted the value of constructivist approaches to understanding communication as a negotiation of meaning between the parties to the communication (Craig, 1999), which was important for the conduct of the research.

Chapter 3 outlined the methodological framework for the research project. Given the importance of including various stakeholder perspectives, such as those of police, lawyers, judges, and forensic scientists in the research, a philosophical stance of dialectical pluralism was adopted. This stance explicitly values diverse perspectives and approaches (Johnson, 2012). From the stance of dialectical pluralism, a sequential mixed methods program of research was undertaken (Creswell & Plano Clark, 2011). A two-stage program of research was designed to address the research aims of outlining current communication practices, assessing their effectiveness, and making recommendations to enhance practice.

In addition to contributing to the thesis by outlining the methodological approach to be applied, this chapter contributed to the broader literature within mixed-methods research. It did so by responding to a call for mixed-methods researchers to articulate their philosophical stances (Alise & Teddlie, 2010). The chapter illustrated some of the key philosophical considerations undertaken in developing the methodology for the project and how they were resolved in practice.

Content Analyses: Expert Conclusions and Reports

Given the rationale established in Chapter 2 which highlighted the dearth of research on communication via expert reports, **Chapters 4, 5 and 6** explored expert reports. Essentially, because expert opinion is formally communicated to police and lawyers (and sometimes to judges) via such reports (Rothwell, 2010), the difficulty level of such reports was explored with non-scientist readers in mind. Chapter 4 reported a preliminary study of the readability of expert conclusions written for an international proficiency test of forensic comparison of glass. In that chapter, I drew from research in education, medicine (patient literacy), and psychology to develop criteria for assessing the readability of expert conclusions. The study established an empirical basis that suggested that the expert conclusions would be difficult for non-experts to read and understand.

In Chapters 5 and 6, given the empirical basis for further exploration of expert reports established in Chapter 4, I obtained samples of case reports of forensic comparison of glass and of DNA from Australian jurisdictions. In Chapter 5, I further refined the methodological approach to examining the readability of documents in their entirety, conducting a review of past studies of readability from various theoretical perspectives. In line with the constructivist approach to communication outlined in Chapter 2, and the theoretical approach adopted in the research project (Chapter 3), I intentionally adopted a broad and holistic approach (following Halliday & Martin, 1993). To develop criteria for assessing readability, I drew from theory on how readers make meaning from text, past research on readability, judicial practice notes, and the samples of expert conclusions and reports that I had obtained. The chapter contributes to research on readability by synthesising past research in the field. As noted in the chapter, regardless of the theoretical perspective adopted, readability studies considered criteria under one or more of the categories of: content and sequence; language; and format.

In Chapter 6, I applied the readability criteria developed in Chapter 5 to an assessment of the readability of Australian reports of forensic biology (DNA). Collectively, Chapters 4, 5, and 6 contribute empirical research findings that support recommendations for improving the structure and language of expert reports (e.g., European Network of Forensic Science Institutes [ENFSI], 2015; Found & Edmond, 2012; NAS, 2009). Related to Chapters 4, 5, and 6, the Appendix includes a paper in which I outline the development of the methodology (directed content analysis) for these studies on the readability of expert reports. The paper provides an illustrated example of the development and use of the methodology for other researchers and research students who are interested in directed content analysis.

Integration of Results of Content Analyses

In **Chapter 7**, a chapter co-authored with Dr Kristy Martire and Dr Sally Kelty, I situated the three readability studies outlined in Chapters 4 to 6 in the context of other Australian research on reporting. Recommendation 2 of the 2009 National Academy of Science Report on *Strengthening Forensic Science in the United States* was that the form and language of reporting be standardised. I evaluated the readability studies in light of Recommendation 2 (NAS, 2009) and the development of national standards, specifically *Forensic Analysis – Part 4: Reporting* (Standards Australia, 2013). This co-authored chapter contributed a summary of recent Australian research from two universities that contributes towards addressing Recommendation 2 of the NAS Report (2009). The chapter indicated that Australian reporting practices already address many recommended criteria and are currently undergoing development and improvement. As noted in the chapter, discipline-specific standards are being developed by scientific working groups, and these standards will likely impact on forensic scientific reporting throughout Australia.

As documented in Chapter 6, many of the same issues for readability were relevant in reports of forensic comparison of glass and DNA. Specific recommendations were made in Chapters 4, 5, and 6 to enhance the readability of expert conclusions and reports in forensic biology (DNA) and forensic chemistry (forensic comparison of glass). In **Chapter 8**, the generalizable recommendations for readability from Chapters 4, 5, and 6 were synthesised and outlined for forensic scientists of all disciplines. As argued in Chapters 7 and 8, the recommendations for readability that I proposed on the basis of the studies reported in Chapters 4-6 can be applied to expert reports in any scientific discipline, in conjunction with meeting other guidelines.

The guidelines proposed by Standards Australia (2013) are relatively non-prescriptive, and thus the recommendations are compatible with these. The ENFSI Guideline (2015, p. 11) specifically acknowledges the need for the principle of transparency and states that: “The report should be written in such a way that it is suitable for a wide audience of readers (i.e., participants in the justice system).” Yet the ENFSI Guideline does not include specific guidance on how to achieve this. The recommendations for readability, which I have proposed in Chapter 8, address this need, as they aim to help achieve balance between scientific accuracy and layperson understanding. They do this by providing specific and practical guidance for case-reporting scientists on the content and sequence of reports, the language used in them, and the format.

Interviews: Practitioners' Perceptions

Having explored the readability of expert reports, **Chapters 9 and 10** aimed to explore the communication needs of the practitioners, who write or read the reports. Past studies had tested whether readers understood the weight of evidence in written form (e.g., de Keijser & Elffers, 2012). Such studies assume that understanding of the weight of evidence is the most relevant component of practitioners' understanding. By contrast, the present research did not flow from such an assumption. Instead, this study sought practitioners' experiences and perceptions about the communication of forensic science to ascertain whether their communication needs were met. Interviews were conducted with practitioners from forensic science, policing, and law over a period of approximately one year, during which time I was able to engage deeply with the interview content. The studies reported in Chapters 9 and 10 indicated that practitioners supported the recommendations to enhance readability of expert reports (Chapter 8). Practitioners' suggestions to improve communication largely reflected those recommendations. This practitioner input can be seen as providing one form of legitimation for the research (Collins, Onwuegbuzie, & Johnson, 2012).

The interviews with police investigators and forensic scientists in Chapter 9 were analysed in light of approaches to communication outlined in Chapter 2. The analyses highlighted that communication between police and forensic scientists in addition to the expert report was necessary and was valued highly by those practitioners. This was particularly evident in serious cases, or in cases with complex science, or when police investigators had not used the scientific discipline in previous cases. Chapter 9 contributes deeper understanding about the supplementary communication between police investigators and forensic scientists during an investigation from crime scene to court. For example, communication and interactions between practitioners in addition to the expert report were not only of practical necessity (e.g., to outline the request for scientific examination) but also fulfilled a function of on-the-job learning about forensic science for police investigators. Moreover, they provided forensic scientists with experience in pitching their explanations about forensic science at an appropriate level for a layperson.

The NAS Report (2009) also recommended that forensic scientific laboratories be separated from policing organisations. This chapter provided a basis from which to explore further the organisation of forensic science laboratories in relation to policing. Importantly, as argued by Maguire, King, Wells, and Katz (2015), it seemed that the recommendation that forensic science be separated from policing should not be adopted wholesale. The chapter highlighted a number of advantages to practitioners from policing and forensic science when their agencies shared an organisational umbrella, as well as when they did not, depending on the particular local context.

Chapter 10 explored the communication of expert opinion between forensic scientists to legal practitioners in the lead-up to court and at trial. The chapter highlighted that expert evidence is shaped by law, for example in admissibility decisions and in appeals. The chapter considered the communication of expert evidence in light of the idealisation of science (Mnookin, 2007), in which the fallibility of science as a human endeavour can tend to be forgotten. The results of the study indicated that practitioners perceived that expert evidence was co-presented by forensic scientists and legal practitioners. Therefore, interaction and communication between legal practitioners and forensic scientists in serious cases played an important role in enhancing practice, to co-present expert opinion coherently to the jury. The study noted some particular difficulties for criminal defence barristers in this regard and the need to think creatively to address the issue of lack of access for procedural fairness.

Although the differences between law and science are often emphasised, Chapter 10 highlighted the cross-disciplinary similarities. Practitioners on both sides of the divide expressed concern about juror understanding. Moreover, they aimed to facilitate juror understanding through thoughtful preparation and coherent presentation of information about forensic science and the overall case for the jury. It is worthy of note that Roberts (2013; 2015) arrived at a number of similar conclusions to those presented in the paper through an argument based on the foundations and development of criminal procedure in the English courts. The findings of the study reported in Chapter 10 provide empirical support from practitioner perceptions to further this argument. The findings have implications for the way that tertiary study and professional development are undertaken to foster opportunities for cross-disciplinary understanding in forensic science and law.

Taken together, the findings of interview studies reported in Chapters 9 and 10 illuminate the importance of opportunities for discussion and interaction between forensic scientists and the police investigators and legal practitioners. In line with constructivist approaches to communication, such cross-disciplinary interaction is necessary to facilitate increased mutual understanding. Increased opportunities for cross-disciplinary communication reportedly helped practitioners to make sense of expert opinion to advance their cases through the criminal justice system.

Limitations and Future Research

Participation in the studies reported in this thesis was limited two scientific disciplines and predominantly related to serious criminal cases typically heard in the supreme courts. This research project focused on serious cases and specific subdisciplines of chemistry and biology. Further research that explores communication practices in other disciplines is warranted. Based on police investigators' and legal practitioners' concerns, research on the communication of psychological, psychiatric, and medical expertise is perhaps most pressing. Research is also needed on the reporting practices of forensic disciplines that have not been grounded in scientific research traditions in the same way as have forensic biology and chemistry.

The document studies reported here aimed to assess readability in a holistic way and the recommendations made are compatible with different standards (e.g., *Forensic Analysis – Part 4: Reporting*, Standards Australia, 2013; *ENFSI Guideline*, ENFSI, 2015). Past studies in different fields (e.g., patient education, school psychologists' reports about students written for teachers) have validated recommendations to enhance readability that were based on theory (e.g., Hirsh, Clerehan, Staples, Osborne, & Buchbinder, 2009). Indeed, the findings from interviews provided evidence of practitioner support for the recommendations. However, research with partner jurisdictions, laboratories, and policing organisations is needed to establish the validity of the recommendations for readability in the forensic scientific context. The recommendations could be tested in a number of ways. For example, research could assess reader comprehension as a function of the way the expert reports are written. It could also gauge practitioner feedback on the ease of locating information in the documents and the perceived comprehensibility of such information. Given the unique aspects of the laboratories' approaches to reporting and the operation of the courts in different jurisdictions, a case-study approach may be beneficial in taking into account the local and specific nuances.

Finally, the interview studies aimed to take a holistic approach to obtaining stakeholder feedback, including participants drawn from a number of practitioner groups. Practitioners who were involved in cases at different levels of the criminal justice system reported that the concerns raised were not limited to serious cases. It seemed that difficulties of a lack of time, budget, and expertise may be amplified in some cases in the lower courts. Research that focuses on the experiences and perceptions of practitioners who give or use expert evidence in cases heard in lower courts may be valuable to complement this research. As noted above for expert reports, future case-study research exploring the local contexts of particular jurisdictions would be helpful in this regard, to best meet the communication needs of practitioners within their particular organisational constraints.

Conclusion

This research project explored the effectiveness of the communication of expert opinion to police, lawyers, and judges. Specifically, the readability of expert reports was evaluated and practitioners' experiences and perceptions of the effectiveness of the communication were explored. Increasingly, the communication about forensic science occurs within a social context in which transparency is required (e.g., ENFSI Guideline, 2015; NAS, 2009; Standards Australia, 2013). This can be seen to reflect a trend away from simple deference to expert opinion, to more informed consideration and understanding of such opinion. Overall, the findings of this project indicated that practitioners value the opportunity to negotiate meaning through interdisciplinary communication. Working together was seen by practitioners as the key to writing relevant expert reports, using the findings effectively in investigations, and providing coherent co-presentations of expert opinion in court. The increased need for accountability amongst forensic scientists who hold knowledge, and therefore power, is consistent with educational approaches to explaining expert opinion and a constructivist view of communication of expert evidence.

This research project provides empirical support for the calls to improve the communication of expert evidence. Moreover, it proposed some recommendations that can be implemented within the institutions of the criminal justice system, to support the best use of forensic science. For the most part, the suggested changes offer a simple and practical way to begin to enhance the communication about forensic science in the criminal justice system. The project raised interesting questions about how well the communication about forensic science works within the existing criminal justice system. It highlighted some challenges, which are inherent in the system, and provided insight into some important considerations in Australian jurisdictions for addressing the need for improved communication practices. Continued attention to the effectiveness of the communication will be needed as evidence law and forensic techniques continue to evolve.

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Appendix

Appendix

Directed Content Analysis:
Exploring the Readability
of Forensic Scientists' Written Reports
for Police, Lawyers, and Judges

This appendix has been removed for copyright or proprietary reasons.

This appendix has been published as follows:

Howes, L. M. (2014). Directed content analysis: Exploring the readability of forensic scientists' written reports for police, lawyers and judges. *SAGE Research Methods Cases* [book / online resource]. doi: 10.4135/978144627305014537442